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## 2

## HUMAN EVOLUTION

## LEARNING OBJECTIVES

After reading this chapter, you should be able to:

- 2.1 Explain how cosmologies regarding human origins differ from the scientific view of evolution.
- 2.2 Discuss how the scientific revolution provided the context for the theory of evolution.
- 2.3 Explain how natural selection works.
- 2.4 Describe how early hominins are different from other primates.
- 2.5 Discuss how *Homo habilis*, *Homo rudolfensis*, *Homo floresiensis*, and *Homo naledi* differ from australopithecines.
- 2.6 Discuss the cultural characteristics of *Homo erectus*.
- 2.7 Describe the physical and cultural characteristics of Neandertals.
- 2.8 Discuss the three models of evolutionary development of modern humans.
- 2.9 Describe the cultural features of the Upper Paleolithic.
- 2.10 Discuss the factors of natural selection that influence skin color differences in modern humans.

## THEORY OF EVOLUTION

### 2.1 Explain how cosmologies regarding human origins differ from the scientific view of evolution.

The most profound human questions are the ones that perplex us the most: Who are we? Why are we here? Where did we come from? What is our place in the universe? What is the purpose of our lives? Is there a purpose to our lives? What happens after death? Universally, all peoples have posed these questions throughout time. Most cultures have developed sophisticated beliefs and myths to provide answers to these fundamentally important questions. **Cosmologies** are conceptual frameworks that present the universe (the cosmos) as an orderly system and include answers to those basic questions about the place of humankind in the universe.

### Origin Myths

Traditionally, the questions posed above have been the basis for origin myths, usually considered the most sacred of all cosmological conceptions. Origin myths account for the ways in which supernatural beings or forces formed the Earth and people. They are transmitted from generation to generation through ritual, education, laws, art, and cultural performances such as dance and music. They are highly symbolic and are expressed in a language rich with various levels of meaning. These supernatural explanations are accepted on the basis of faith and have provided partially satisfying answers to these profound questions.

Many origin myths deal with the origin of humans in the context of the origin of the universe. For example, the Navajo Indians traditionally believed that Holy People, supernatural and sacred, lived below ground in twelve lower worlds. A massive underground flood forced the Holy People to crawl through a hollow reed to the surface of the Earth, where they created the universe. A deity named Changing Woman gave birth to the Hero Twins, called Monster Slayer and Child of the Waters. Mortals, called Earth Surface People, emerged, and First Man and First Woman were formed from the ears of white and yellow corn.

Another cosmological tradition, found in India, teaches that life resulted from the opening of a cosmic egg, which is the source of all life. In China, in the religious tradition of Taoism, the male and female principles known as *yin* and *yang* are the spiritual and material sources for the origins of humans and other living forms. *Yin* is the passive, negative, feminine force or principle in the universe, the source of cold and darkness; *yang* is the active, positive, masculine force or principle in the universe, the source of heat and light. Taoists believe that the interaction of these two opposite—yet complementary—principles brought forth the universe and all living forms out of chaos.

### Western Origin Myths

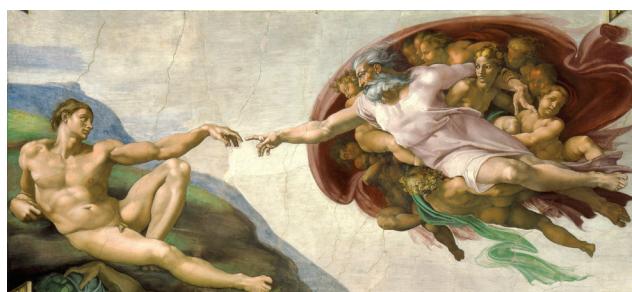
In the Western tradition, the ancient Greeks had various mythological explanations for the origin of humans. One early view was that Prometheus fashioned humans out of water and earth. Another had Zeus ordering Pyrrha to throw stones behind

his back; these stones became men and women. Later Greek cosmological views considered biological evolution. Thales of Miletus (c. 636–546 B.C.) argued that life originated in the sea and that humans initially were fishlike, eventually moving onto dry land and evolving into mammals. A few hundred years later, Aristotle (384–322 B.C.) suggested an early theory of creation through evolution. Based on comparative physiology and anatomy, his argument stated that life had evolved from simple lower forms such as single-celled amoebas to complex higher forms such as humans.

The most important cosmological tradition that influenced Western views of creation is found in the Book of Genesis in the Bible. This Judaic tradition describes how God created the cosmos. It begins with “In the beginning God created the heaven and the earth,” emphasizing that the creation took six days, during which light, heaven, Earth, vegetation, Sun, Moon, stars, birds, fish, animals, and humans were formed. In Genesis, the creator is given a name, Yahweh, and is responsible for creating man, Adam, from “dust” and placing him in the Garden of Eden. Adam names the animals and birds. Woman, Eve, is created from Adam’s rib. Eventually, according to this ancient Hebrew tradition, Yahweh discovers that his two human creations have disobeyed his laws and have eaten fruit from the forbidden tree of knowledge of good and evil. Yahweh expels Adam and Eve from the Garden of Eden.

As generations pass, humans continue to disobey God’s laws. As punishment, God produces a catastrophic flood that destroys all of his creations except Noah and his family, the descendants of Adam and Eve. Noah and his family take two of every animal on an ark built according to God’s directions. Noah, his family, and the different species of animals are saved from the flood on the ark. Eventually, Noah and his family give birth to all the peoples throughout the Earth. Later, as the Judeo-Christian tradition spread throughout Europe, the biblical cosmology became the dominant origin myth in the Western world.

In Europe before the Renaissance, the Judeo-Christian view of creation provided the only framework for understanding humanity’s position in the universe. The versions of creation discussed in the biblical text fostered a specific concept of time: a linear, nonrepetitive, unique historical framework that began with divine creation. These events were chronicled in the Bible; there was no concept of an ancient past stretching far back in time before human memory. This view led some theologians to attempt to calculate the precise age of the Earth on the basis of information in the Bible, such as references to births and deaths and the number of generations. One of the best known of these calculations was done by Archbishop James Ussher of Ireland (1581–1656). By calculating the number of generations mentioned in the Bible, Ussher dated the beginning of the universe to the year 4004 B.C. Thus, according to Bishop Ussher’s estimate, the Earth was approximately 6,000 years old.



Michelangelo di Lodovico Buonarroti Simoni

This painting by Michelangelo in the Sistine Chapel represents the idea of spiritual creation, the dominant worldview in Western cosmology for centuries.

The biblical account of creation led to a static, fixed view of plant and animal species and the age of the Earth. Because the Bible recounted the creation of the world and everything on it in six days, medieval theologians reasoned that the various species of plants and animals must be fixed in nature. God had created plant and animal species to fit perfectly within specific environments and did not intend for them to change. They had been unaltered since the time of the divine creation, and no new species had emerged. This idea regarding the permanence of species influenced the thinking of many early scholars and theologians.

## THE SCIENTIFIC REVOLUTION

### 2.2 Discuss how the scientific revolution provided the context for the theory of evolution.

In the Europe during the Renaissance (c. A.D. 1450), scientific discoveries began to influence conceptions about the age of the Earth and humanity’s relationship to the rest of the universe. Copernicus and Galileo presented the novel idea that the Earth is just one of many planets revolving around the Sun, rather than the center of the universe, as had traditionally been believed. As this idea became accepted, humans could no longer view themselves and their planet as the center of the universe.

This shift in cosmological thinking set the stage for entirely new views of humanity’s links to the rest of the natural world. New developments in the geological sciences began to expand radically the scientific estimates of the age of the Earth. These and other scientific discoveries in astronomy, biology, chemistry, mathematics, and other disciplines dramatically transformed Western thought (Henry 2002).

Among the most dramatic ideas to result from the scientific revolution was the scientific theory of evolution, which sees plant and animal species originating through a gradual process of development from earlier forms. **Evolution** is the process of genetic changes within a population through time. Although it is not intended to contradict cosmologies, it is based on a different kind of knowledge. Cosmological explanations frequently

involve divine or supernatural forces that are, by their nature, impossible for human beings to observe. We accept them and believe in them, on the basis of faith. Scientific theories of evolution, in contrast, are derived from the belief that the universe operates according to regular processes that can be observed. The scientific method is not a rigid framework that provides indisputable answers. Instead, scientific theories are propositions that can be evaluated by future testing and observation. Acceptance of the theory of evolution is based on observations in many areas of geology, paleontology, and biology.

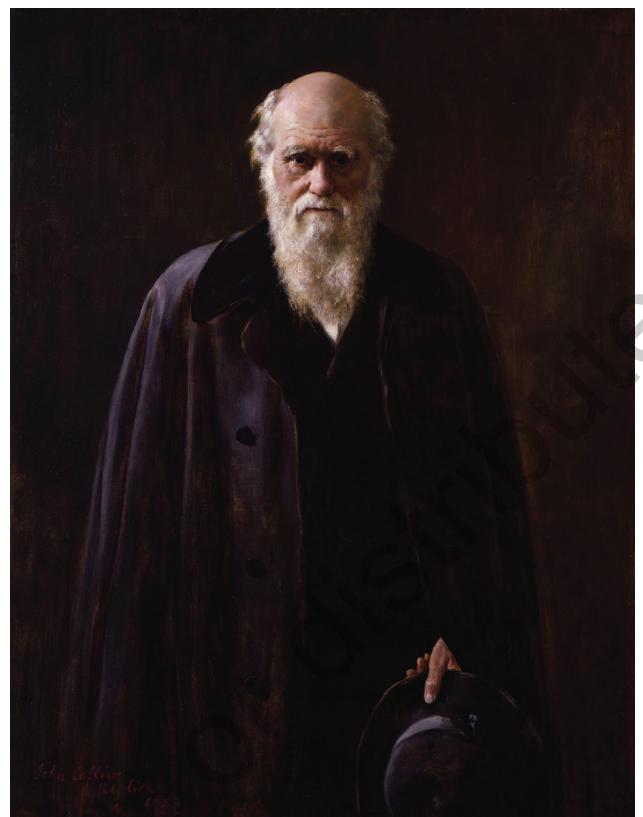
## DARWIN, WALLACE, AND NATURAL SELECTION

### 2.3 Explain how natural selection works.

Two individuals strongly influenced by the scientific revolution were Charles Robert Darwin (1809–1882) and Alfred Russel Wallace (1823–1913), nineteenth-century British naturalists. Through their careful observations and their identification of a plausible mechanism for evolutionary change, they transformed perspectives of the origin of species. Impressed by the variation in living species and their interaction with the environment, Darwin and Wallace independently developed an explanation of why this variation occurs and the basic mechanism of evolution. This mechanism is known as **natural selection**, which can be defined as genetic change in a population resulting from natural or environmental changes that produce differential reproductive success. This is now recognized as one of the four principal evolutionary processes.

Beginning in 1831, Darwin traveled for five years on a British ship, the HMS *Beagle*, on a voyage around the world. During this journey, he collected numerous plant and animal species from many different environments. In the 1840s and 1850s, Wallace observed different species of plants and animals during an expedition to the Amazon and later continued his observations in Southeast Asia and on the islands off Malaysia. Darwin and Wallace arrived at the theory of natural selection independently, but Darwin went on to present a thorough and completely documented statement of the theory in his book, *On the Origin of Species*, published in 1859.

In their theory of natural selection, Darwin and Wallace emphasized the enormous variation that exists in all plant and animal species. They combined this observation with those of Thomas Malthus (1766–1834), a nineteenth-century English clergyman and political economist whose work focused on human populations. Malthus was concerned with population growth and the constraints that limited food supplies had on population size. Darwin and Wallace realized that similar



Charles Darwin (1809–1882).

National Portrait Gallery NPG 1024

pressures operate in nature. Living creatures produce more offspring than can generally be expected to survive and reproduce. For the thousands of tadpoles that hatch from eggs, few live to maturity. Similarly, only a small number of the seeds from a maple tree germinate and grow into trees. In recognizing the validity of this fact, Darwin and Wallace realized that there would be *selection* in which organisms survived. What factors would determine their survival?

Variation within species and reproductive success are the basis of natural selection. Darwin and Wallace reasoned that certain individuals in a species may be born with particular characteristics or traits that make them better able to survive. For example, certain seeds in a plant species may naturally produce more seeds than others, or some frogs in a single population may have coloring that blends in with the environment better than others, making them less likely to be eaten by predators. With these advantageous characteristics, certain species are more likely to reproduce and, subsequently, pass on these traits to their offspring. Darwin called this process *natural selection* because nature, or the demands of the environment, actually determines which individuals (or which traits) survive. This process, repeated countless times over millions of years, is the means by which species change or evolve over time.

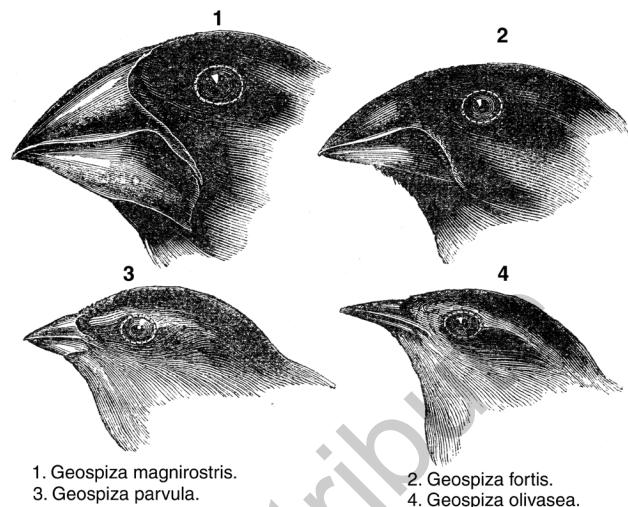
## Examples of Natural Selection

One problem Darwin faced in writing *On the Origin of Species* was a lack of well-documented examples of natural selection at work. Most major changes in nature take place over thousands or millions of years. As a result, the process of natural selection is often too slow to be documented in a researcher's lifetime. However, when animals or plants are exposed to rapid changes in their environment, we can actually observe natural selection in action.

A classic case of natural selection is illustrated by the finches of the Galápagos Islands, located about 500 miles off the coast of South America. Darwin studied these birds when he visited the islands during his travels on the HMS *Beagle*. Volcanic in origin and cut off from the South American mainland, the Galápagos have a diversity of species related to, but distinct from, those of South America. Darwin was struck by how the geographic isolation of a small population could expose its members to new environmental conditions where different adaptive features might be favored. Darwin described the variation in the islands' finches: In general, the birds have rather dull plumage and are quite similar, except in the size and shape of their beaks—a feature that is closely related to the ways in which the birds obtain their food. Some species of finch, for example, have short, thick beaks that they use to eat seeds, buds, and fruits, while others have long, straight beaks and subsist primarily on nectar from flowers.

The finches on the island of Daphne Major in the Galápagos were the focus of a long-term research project by Peter and Rosemary Grant, beginning in 1973 (Grant 1999; J. Weiner 1994). The island is small enough to allow researchers to study intensively the island's flora and fauna and provide an unambiguous demonstration of natural selection in operation. The Grants and their students focused on two species of finch—the medium ground finch and the cactus finch. Over time, every finch on the island was captured, carefully measured and weighed, and also tagged so that each bird could be identified in the field. The diet of the birds was documented and the availability of food resources charted. A dramatic change in the finches' food resources occurred between mid-1976 and early 1978 as a result of a drought. The lack of rainfall led to a decrease in the food supplies favored by smaller-beaked finches. The remaining food consisted of larger, harder seeds that were difficult for finches with small beaks to break open. On the other hand, finches with larger, heavier beaks were able to more easily crack and extract food from hard-shelled seeds. Not surprisingly, many of the finches with smaller beaks died of starvation during the drought.

The variation in beak size is a good illustration of how natural selection may act on different species, but it also illustrates the significance of variation within individual species. Of the



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Finches of the Galápagos Islands showing their different beaks due to evolution and natural selection, first documented by Charles Darwin.

more than 1,000 medium ground finches found on the island at the beginning of the Grants' study, only 180 remained after the drought. Notably, the finches that survived had a larger average beak size than that of the population prior to the drought. As beak size is an inherited characteristic, the new generations of birds born after the drought also had a larger average beak size. This case study illustrates how natural selection can eliminate maladaptive traits from a population and select for features that help ensure survival and, ultimately, reproductive success for some members of a species. Many modern scientists believe that new species emerge when small populations become isolated from the parent group and encounter new selective pressures that may favor different characteristics.

Natural selection is currently viewed as one of four major guiding forces in the evolution of species. It enabled Darwin to explain the mechanisms of biological evolution, and it remains a powerful explanation for the development of living species of plants and animals.

## Principles of Inheritance

Darwin contributed to the modern understanding of biological evolution by thoroughly documenting the variation of living forms and by identifying the process of natural selection. But Darwin did not understand how individuals pass on traits to their offspring. This discovery, and the study of heredity, was left to the experiments of an Austrian Catholic monk, Gregor Mendel (1822–1884). During the 1860s, Mendel began a series of breeding experiments with pea plants. The results of these experiments revolutionized biological thought. Although his findings were not recognized until the twentieth century, they have shaped our basic understanding of inheritance. Through his experiments, Mendel established the new science

of **genetics**, a field of biology that deals with the inheritance of different characteristics. We now know Mendel's particles or units of inheritance as *genes*. For the purposes of this discussion, a **gene** can be considered a deoxyribonucleic acid (DNA) sequence that encodes the production of a particular protein or portion of a protein. In combination, these DNA sequences determine the physical characteristics of an organism. Genes, discrete units of hereditary information, may be made up of hundreds or even thousands of DNA sequences.

Most sexually reproducing plants and animals have two genes for every trait, one inherited from each parent. More than 4,500 human traits are inherited in this manner. However, while some human characteristics are inherited as discrete traits, the majority are passed on in a more complicated fashion. Many physical characteristics in humans are referred to as *polygenic* or *continuous traits* that display a graded series determined by a multiplicity of genes. They include many of the most visible aspects of human features, such as height, skin color, and hair color, and consequently were often used as the basis for racial classifications.

According to the most recent research on the human genome, it is estimated that a human being inherits between 20,000 and 25,000 genes that specify various characteristics (Bernstein et al. 2012).

## The Evolution of Life

Modern scientific findings indicate that the universe as we know it began to develop 13.8 billion years ago. Approximately 4.545 billion years ago, the Sun and the Earth formed, and about a billion years later, the first life forms appeared in the sea. Through the evolutionary processes, living forms that developed adaptive characteristics survived and reproduced. Geological forces and environmental alterations brought about both gradual and rapid changes, leading to the evolution of new forms of life. Plants, fish, amphibians, reptiles, and eventually mammals evolved over millions of years of environmental change.

About 67 million years ago, a family of mammals known as **primates**—a diverse group, introduced in Chapter 1, with similarities such as increased brain size, stereoscopic vision, grasping hands and feet, longer periods of offspring, dependence on their mothers, a complex social life, and enhanced learning abilities—first appeared in the fossil record. Early primates include ancestors of modern *prosimians*, such as lemurs, tarsiers, and lorises. Later primates that appeared in the fossil record include anthropoids, such as monkeys, apes, and humans, who shared a common ancestor and have some fundamental similarities with one another. We can trace the striking similarities among primates to a series of shared evolutionary relationships. Many people hold a common misconception about human evolution—the mistaken belief that humans descended from modern apes such as the gorilla and chimpanzee. This

is a highly inaccurate interpretation of both Darwin's thesis and contemporary scientific theories that suggest that, while humans and modern apes share common evolutionary origins, each rests at the end of its own evolutionary lineage. Millions of years ago, some animals developed characteristics through evolutionary processes that gave rise to later primates, including modern chimpanzees, gorillas, and humans.

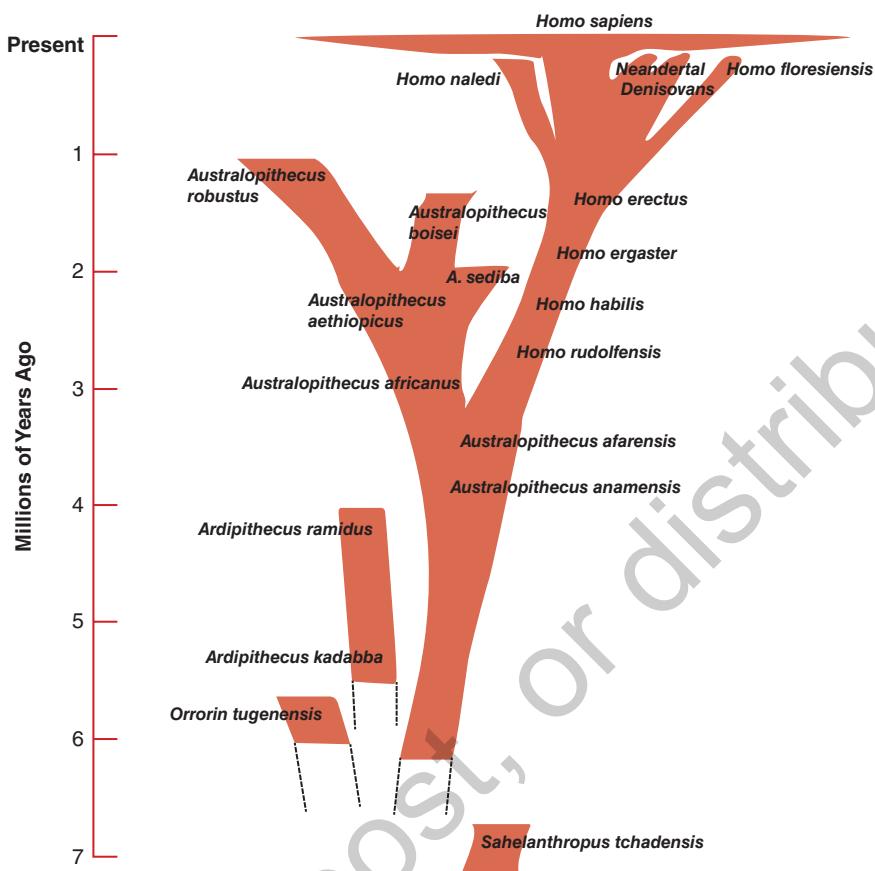
## HOMININ EVOLUTION

### 2.4 Describe how early hominins are different from other primates.

Scientists have traditionally used physical characteristics that reflect shared adaptive histories in classifying primates—placing them into various families, genera, and species. In the past decade, the unraveling of genetic codes has revealed the specific genetic links between living primate species. These data indicate that humans and the African apes are more closely related than either group is to the orangutans. In recognition of this relationship, orangutans, chimpanzees, and gorillas, as well as humans and their ancestors, are sometimes now all placed into family Hominidae. The subfamily Ponginae is then used to just refer to the orangutans, while the subfamily Homininae includes the gorillas, chimpanzees, and humans. Humans and their ancestors are then placed in their own tribe, Hominini (hominin), to indicate their unique characteristics.

Anthropologists have been evaluating hypotheses regarding hominin evolution for the past 150 years (see Figure 2.1). **Hominins**, the family of primates that includes the direct ancestors of humans, share certain subtle features in their teeth, jaws, and brain. However, by far the major characteristic that identifies them as a distinct group is the structural anatomy needed for **bipedalism**, the ability to walk erect on two legs. Within the Hominini, members of genus *Homo*, including modern humans, are further characterized by increase in cranial capacity.

Fossil evidence provides a clear record of the evolution of the human species from a small-brained bipedal ape over the past 10 million years. Some people believe that paleoanthropologists are searching for the “missing link” between us and other primate creatures such as the chimpanzee. However, paleoanthropologists are skeptical of the popular phrase “missing link” because it implies that evolution develops in a linear path of development with well-defined junctures demonstrating common ancestors and linkages. This popular view assumes that there is a single transitional link between a living ape and a living human. The reality of the fossil record demonstrates that evolution is much messier, with different branches evolving at varying rates, new traits emerging numerous times independently, and populations diverging and interbreeding, producing splits over many years

**FIGURE 2.1** ■ A Schematic Diagram of Hominin Evolution

across multiple continents. Rather than a tree of life with distinctive branches showing common ancestors, the fossil record is much more like a dense, tangled thorny bush with overlapping lines of descent (Quammen 2018). Thus, there is no single “missing link” between earlier primates such as the chimpanzee and humans. Yet, some fossils indicate transitional forms of creatures that have both apelike and humanlike characteristics.

Some fossil evidence dated between 6 and 7 million years ago (mya) in Chad is fragmentary but intriguing for understanding early evolution (Brunet et al. 2002). This specimen is named *Sahelanthropus tchadensis*. The fossil evidence indicates an apelike sloping face, a very small brain, small humanlike canine teeth, and a prominent brow ridge. The specimen has a complete, though distorted, cranium. The spinal cord is centered underneath the cranium, suggesting an upright bipedal creature, but since the finds are fragmentary, it is difficult to determine full bipedalism.

Two other intriguing new fossil discoveries of early creatures were described in 2001, both from Kenya. The first is *Orrorin tugenensis* (nicknamed Millennium Man), a collection of postcranial and dental material dated at about 6 mya

(Pickford, Gommery, and Treil 2002). The postcranial fossils suggest a primitive form of bipedalism. These early finds of very primitive creatures are fascinating because they may suggest a common ancestry with the later evolution of our genus *Homo*, rather than *Australopithecus*, described later.

A significant collection of 110 fossil remains from a female hominin discovered by paleoanthropologist Tim White and colleagues in Ethiopia and dated at 4.4 mya presents new understandings of early hominin evolution (Lovejoy et al. 2009; T. White et al. 2009; T. White et al. 2003; T. White et al. 2015). These fossils are so different from early australopithecines (described later) that they have been classified as a new genus, *Ardipithecus ramidus* (Ardi). Ardi had a robust frame and was about four feet tall. The hands and digits of Ardi are more similar to gorillas than to later creatures. She also had a grasping apelike toe that helped her climb in the trees. However, the pelvis and other postcranial traits indicate some bipedalism. Again, bipedalism is the major characteristic that distinguishes hominins from earlier primates. Further evidence of these fossils is needed to determine whether they are the earliest true hominins yet to be discovered.

## CRITICAL PERSPECTIVES

### CREATIONISM, INTELLIGENT DESIGN, AND EVOLUTION

Despite the compelling and increasing scientific evidence supporting evolution, not all segments of American and Western society have accepted the geological, genetic, and fossil data that are the basis of evolutionary theory (Petto and Godfrey 2007; Young and Largent 2007). Various versions of creation that rely on literal interpretations of the Bible are taught by some Christian, Jewish, and Islamic groups, as well as other religious denominations. For example, many members of the Old Order Amish (discussed in Chapter 3) accept an extreme literal reading of the biblical passage that refers to “four corners of the Earth held up by angels” and believe that the Earth is a two-dimensional flat plane. Members of the International Flat Earth Society have similar beliefs about a flat Earth (E. Scott 2009). These views reflect the ancient Hebrew description in the biblical passages referring to the Earth as a flat disk floating on water with the heavens held up by a dome (or firmament) with the Sun, Moon, and stars attached to it.

In the nineteenth century, some individuals attempted to reconcile a literal reading of the account of creation in Genesis 1:2 by translating the Hebrew term *day* as a nonspecific period of time that could last thousands or millions of years long, rather than twenty-four hours (Sedley 2007). Some contemporary creationists’ teachings expose similar views; they are sometimes referred to as “day-age creationists.” However, the vast majority of activists in the campaign against teaching evolution call themselves “progressive creationists.” The progressive creationists accept the modern scientific view of the big bang and that the Earth is billions of years old, but do not accept the theory of evolution. They believe that God not only created the big bang, but also created separate “kinds” of plants and animals with genetic variations that resulted in the development of contemporary species of living organisms.

A group of creationists who have actively campaigned against the teaching of evolution call themselves “scientific creationists,” represented by the Institute for Creation Research. The members of this group propose a biblically based explanation for the origins of the universe and of life. They reject modern physics, chemistry, and geology concerning the age of the Earth. They argue that the entire universe was created within a period of six days, based on the account in Genesis 1:2. They believe that the universe was spontaneously created by divine fiat 6,000 to 10,000 years ago, challenging evidence for billions of years of geological history and fossil evidence. These creationists explain the existence of fossilized remains of ancient life by referring to a universal flood that covered the entire Earth for forty days. Surviving creatures were saved by being taken aboard Noah’s ark. Creatures that did not survive this flood, such as dinosaurs, became extinct (Gish 1995). This creationist view is taught in some of the more fundamentalist denominations of Protestantism, Judaism, and Islam.

Scientific creationists read the texts and theories presented by biologists, geologists, and paleontologists and then present their arguments against the evolutionary views. They do very little, if any, direct biological or geological research to refute evolutionary hypotheses (Rennie 2002). Their arguments are based on biblical sources mixed with

misinterpretations of scientific data and evolutionary hypotheses. The cosmological framework espoused by the scientific creationists is not based on any empirical findings. For example, scientists around the world find no physical evidence of a universal flood. Local floods did occur in the Near East and may be related to the story of Noah that appears in the Bible (and in earlier Babylonian texts). But to date, no evidence exists for a universal flood that had the potential to wipe out human populations worldwide or to cause the extinction of creatures such as dinosaurs (Isaak 2007).

A more recent form of creationism has been referred to as “intelligent design creationism” (Gross and Forest 2004; Petto and Godfrey 2007). The historical roots of this conceptual stance go back to philosophers such as Plato and Aristotle in the Greek tradition, who suggested that a spiritual force structured the universe and society. These ideas were Christianized by Saint Thomas Aquinas (1225–1274) and European scholars during the medieval period. In the nineteenth century, theologian William Paley (1743–1805) argued that one could see proof of God’s existence by examining the Earth and the remarkable adaptations of living organisms to their environments, using the famous analogy that if we found a watch, we would have to assume that there was a watchmaker—we can see God’s plan as we observe the natural world (Paley, 1802). Two contemporary theorists who support this position are Lehigh University’s biochemist Michael Behe, author of *Darwin’s Black Box* (1996) and *Darwin Devolves* (2019), and philosopher and mathematician William Dembski, professor of science and culture at Southern Evangelical Seminary in Matthews, North Carolina, author of the book *Intelligent Design* (1999).

Debates between intelligent design proponents and other researchers have been extensive and, at times, quite spirited (Rennie 2002; Shanks 2004; Shanks and Joplin 1999). Critics of intelligent design creationism note that Behe, Dembski, and their followers concede that microevolution and macroevolution have occurred, but they contend that some biological phenomena and the complexity of life cannot be explained by modern science and that this complexity itself is proof that there must be an intelligent supernatural designer. Although most scientists would not rule out the possibility of supernatural creation, they do require evidence. In this respect, intelligent design has failed to provide a more compelling argument of human origins than evolutionary theory.

Given these diverse perspectives, is there any common ground between religious explanations of human origins and scientific theories? Surveys indicate that a surprising number of Americans assume that the creation–evolution controversy is based on a dichotomy between believers in God and secular atheists who are antireligious. This is incorrect. There are many varieties of both religious perspectives and evolutionary explanations, many of them compatible. Scientists and others who accept evolution are not necessarily atheists (Pennock 2003; E. Scott 2009). One major view of evolution is known as *theistic evolution*, which promotes the view that God creates through the evolutionary processes. Supporters of this perspective accept the modern scientific findings in astronomy, biology, genetics, and fossil and

geological evidence, but see God as intervening in how evolution takes place. Theistic evolution is the official view accepted by the Roman Catholic Church; it was reiterated by Pope John Paul II in 1996. In this statement, John Paul II emphasized that evolution was not just “theory,” but was based on an enormous amount of empirical evidence, or “facts.” The Roman Catholic theological position is that although humans may indeed be descended from earlier forms of life, God created the human soul. Other contemporary mainstream Protestant, Jewish, Muslim, Hindu, and Buddhist scientists also accept theistic evolution. This position sees no conflict between religion and science and reflects a continuum between the creationist and evolutionary views.

Another view of evolution is sometimes referred to as *materialist evolutionism* or *philosophical materialism*. Scientists and philosophers who hold this view believe that the scientific evidence for evolution results in a proof of atheism. Charles Darwin recorded in his memoirs how he vacillated between muddled religious faith, atheism, and what he later accepted as agnosticism (the belief that one cannot know as humans whether God exists or not) (Desmond and Moore 1991). Survey polls demonstrate that most Americans believe materialist evolutionism is the dominant view among scientists, despite the fact that this is not the case. Because it challenges religious interpretations, it is one of the primary reasons why some fundamentalist religious-based groups have opposed the teaching of evolution in the public schools in the United States.

In actuality, many scientists accept theistic evolution or other spiritual views along with scientific theories. For example, one of the leading critics of intelligent design creationism is the practicing Roman Catholic biologist at Brown University, Kenneth Miller. Miller has authored a book called *Finding Darwin’s God: A Scientist’s Search for Common Ground Between God and Evolution* (2000). In this book, Miller draws on biology, genetics, and evolutionary data to challenge intelligent design proponents’ claims that the complexity of life demonstrates an intelligent designer. Paul Davies, a Protestant theologian and philosopher who authored the book *The Fifth Miracle* (2000) about faith and the evolution of life, is also

critical of the intelligent design creationist model and relies on the empirical findings in science and evolution to refute their claims.

These individuals and other scientists accept theistic views of evolution, but they emphasize that scientific understanding of the universe and life must be based on the methods of *naturalism*. This *methodological naturalism* requires the scientist to rely on “natural” or “materialist” (biological and physical) explanations rather than spiritual or theological explanations for examining the universe and evolution, *but it does not compel one to accept atheism*. In fact, many major philosophers and scientists, such as anthropologist Eugenie Scott (former director of the National Center for Science Education) and the famed Albert Einstein, argued that one cannot prove or disprove the existence of God through the use of science. Methodological naturalism does not result in a conflict between faith and science. Rather, faith and science are viewed as two separate spheres and modes of understanding the world. This method of naturalism coincides with the teachings of the Roman Catholic position and many mainstream Protestant, Jewish, Muslim, Hindu, and Buddhist traditions.

Evolutionary explanations and other scientific theories often fail to satisfy our deep spiritual questions and moral concerns. While science can give us some basic answers about the universe and life, it cannot reveal spiritual insights. And yet, a scientific perspective does tend to leave us in a state of “spiritual awe” as described by Darwin in the famous closing passage of *On the Origin of Species*: “There is grandeur in this view of life.”

### Questions to Ponder

1. Can accounts of creation such as that found in Genesis 1:2 be evaluated empirically?
2. Have any of the scientific creationist claims convinced you of the falsity of evolution?
3. Do you think that faith and science are compatible when assessing the scientific record regarding evolution?

### *Australopithecus*

An enormous amount of fossil evidence for at least six different species of australopithecines has been discovered in Africa. The genus *Australopithecus* means “southern ape” as it was first found in South Africa. The most complete early form of this genus, found in the Afar region of Ethiopia, is known as *Australopithecus afarensis*. It was discovered in 1974 by a joint American–French team of paleoanthropologists led by Donald Johanson. The best-known *A. afarensis* individual is popularly known as “Lucy” (named after the Beatles’ song “Lucy in the Sky With Diamonds”) (Johanson and Edey 1981). Forty percent of the skeleton of this individual was preserved, allowing paleoanthropologists to determine its precise physical characteristics. Lucy is a female *Australopithecus* with features such as a small cranium, or skull—440 cubic centimeters (cc), compared

with a capacity of 1,000 to 1,800 cc for modern humans—indicating a small brain and large teeth. Fragments of Lucy’s skull resemble that of a modern chimpanzee; however, below the neck, the anatomy of the spine, pelvis, hips, thighbones, and feet has characteristics of a bipedal creature, though one that did a lot of climbing also (Kappelman et al. 2016). Lucy was fairly small, weighing approximately seventy-five pounds, and was about 3.5 to 4 feet tall. Lucy is dated at 3.2 mya.

There are many other *A. afarensis* fossils, including skulls that have been discovered. For example, other important discoveries came in 1975 at a fossil locality at Hadar (Ethiopia) known as Site 333. Johanson and his crew found many hominin bones scattered along a hillside. Painstakingly piecing them together, the researchers reconstructed thirteen individuals, including both adults and infants, with anatomical characteristics similar to those of Lucy. Experts hypothesize that these



Lannas / Alamy Stock Photo

This photo shows a reconstruction of "Lucy," an *Australopithecus afarensis* discovered by Donald Johanson and his team of paleoanthropologists in 1974.

finds may represent one social group that died at the same time for unknown reasons. The *A. afarensis* fossils discovered at Hadar have been dated between 3 and 4 mya, making these some of the earliest well-described hominin remains.

Another fascinating discovery from Hadar is the popularly named "Dikika baby" or "Lucy's baby" found at a site called Dikika, located just a couple of miles from where the Lucy find was discovered. Like the Lucy discovery, the Dikika find is the well-preserved remains of an *A. afarensis*, but whereas Lucy was an adult, the Dikika fossil is of a three-year-old child (Alemseged et al. 2006). The find consists of an almost complete skull, the entire torso, much of the legs, and parts of the arms. The completeness of this find is especially exciting because the smaller bones of young children are even more unlikely to survive the ravages of time than are those of adults.

In 2008, a nine-year-old boy, Matthew Berger, son of South African paleoanthropologist Lee Berger, was chasing his dog when he stumbled over some fossilized bones. His father studied the bones at a site called Malapa and discovered that they were from a previously unknown hominin species, now known as *Australopithecus sediba* (L. Berger 2012; S. A. Williams, Desilva, and De Ruiter 2018). Following ten years of research,

the Malapa hominin was dated at 1.977 mya. Two partial skeletons that have been analyzed, including three-dimensional scanning, show that *A. sediba* was a small creature weighing just seventy-seven pounds. But it had a unique combination of traits such as hands that were capable of precise manipulations and a powerful grip for climbing trees. The shoulders and forelimbs are very primitive, but the pelvis and lower limbs indicate bipedalism. Thus, *A. sediba* represents one of the creatures evolving sometime between *A. afarensis* and the emergence of the *Homo* line.

## HOMO

### 2.5 Discuss how *Homo habilis*, *Homo rudolfensis*, *Homo floresiensis*, and *Homo naledi* differ from australopithecines.

The first representatives of our own species first appear in the fossil record about 2.5 mya. The earliest representatives of the genus include/are represented by *Homo habilis*, *Homo rudolfensis*, *Homo floresiensis*, and *Homo naledi*. The average size of the skull of *H. habilis* is 640 cc, indicating a much larger brain than that of the australopithecines. However, *H. habilis* fossils indicate that this creature had some apelike features such as climbing abilities aside from upright bipedalism. The *H. rudolfensis* skull had a cranial capacity of 775 cc, considerably larger than *H. habilis*. *H. habilis* and *H. rudolfensis* were contemporaries and date from between 2.2 and 1.6 mya; therefore, they coexisted with later species of australopithecines (Leakey et al. 2012).

Two more forms of the *Homo* lineage, *H. floresiensis* and *H. naledi*, have been discovered and analyzed more recently. Although *H. floresiensis* was first discovered at a site known as the Liang Bua cave on the island of Flores in Indonesia in 2003, it has been extensively reanalyzed since then. *H. floresiensis* was a diminutive creature popularly nicknamed "the Hobbit" based on its small body size and small cranium. Skeletal material from nine individuals has been recovered, with one complete skull. The cranial capacity of the skull was very small at 380 cc, in the range of chimpanzees or early australopithecines. The height of *H. floresiensis* is estimated at three feet, six inches. The remains at Liang Bua cave are dated at 86,000 mya, but at another site on Flores, fossils are dated at 700,000 mya. Following fifteen years of research based on comparisons of skeletal material from both Africa and Asia, paleoanthropologists have concluded that *H. floresiensis* is a late survivor of *H. habilis* or its close descendants, indicating an early migration from Africa to Asia (Argue et al. 2017).

In 2013, a cache of fossil bones known as *Homo naledi* was discovered in a remote cave chamber of the Rising Star cave system in South Africa. The cave was so deep with narrow passages that South African paleoanthropologist Lee Berger had to recruit "skinny" and mostly female paleoanthropologists and archaeologists through Facebook in order to carry out



Courtesy of John Hawks

This photo shows the enormous amount of fossil evidence for *Homo naledi* discovered in the Rising Star cave in South Africa.

the excavation (L. Berger and Hawks 2017). Over 1,500 fossil bones were found from fifteen individuals of various ages. One of the adult individuals had a complete skull along with other cranial evidence. This fossil evidence suggests a small brain for *H. naledi* ranging from 460 cc to 565 cc (L. Berger and Hawks 2017; L. Berger et al. 2015; Holloway et al. 2018). The cranial, dental, and postcranial remains consist of both humanlike characteristics and australopithecine traits. However, surprisingly, following sophisticated dating techniques, the fossil assemblage was dated between 236,000 and 335,000 years ago. This means that *H. naledi* existed at the same time as other later hominins including early forms of *Homo sapiens*. One other intriguing aspect debated by paleoanthropologists and archaeologists regarding the *H. naledi* is that although there were no tool artifacts found, it may be one of the first intentional burials deep within this South African cave.

### Early Stone Tools: The Lower Paleolithic

The first tools were very likely *unmodified* pieces of wood, stone, bone, or horn that were picked up to perform specific tasks and then discarded soon afterwards. Although it is perhaps tempting to associate the manufacture of the first tools with the larger-brained members of our own genus *Homo*, the oldest stone tools clearly predate the earliest representative of the genus. The oldest evidence for unmistakable stone tool use was found at a site called Lomekwi near Kenya's Lake Turkana by a team led by archaeologist Sonia Harmand (Harmand et al. 2015). These stone tools, over 150 of them, were dated at 3.3 mya. Other, indirect evidence for early stone tool use comes from cut marks left on two bones recovered in Dikika, Ethiopia, and dated to roughly 3.4 mya (McPherron et al. 2010). These early dates suggest that australopithecines may have been engaged in stone tool production.

Other recognizable stone tools dating back just over 2.6 mya are found at several sites in eastern and southern Africa (Semaw et al. 2003). These early stone tools are called *chopper*

*tools* or *hammer stones*. Hammer stone tools were used to knock off "flakes" to form choppers. This technique is referred to by archaeologists as *percussion flaking*. Called Oldowan tools (because they were first discovered at Olduvai Gorge in Tanzania), these tools could be used for cutting the hides of animals, cutting wood, and possibly shaping wooden tools (Keeley and Toth 1981).

A recent excavation of a site in Shangchen in southern China has unearthed some early stone tools outside Africa dated at 2.1 mya (Zhu et al. 2018). This discovery along with the conclusions about the ancestral line of *Homo floresiensis* in Indonesia as described earlier indicates that early hominins such as *Homo habilis* or its closest descendants were migrating long distances from Africa to Asia at a very early time period.

The importance of the discovery of the artifacts is that they suggest that early hominins had the intellectual capacity to fashion stone tools to develop a more effective means of subsistence. This innovation indicates an increased brain size, which led, in turn, to new forms of complex learning. These technologies mark the beginnings of what is known as the Lower Paleolithic period of hominin evolution, or the earliest period of the Old Stone Age.

## HOMO ERECTUS

### 2.6 Describe the cultural characteristics of *Homo erectus*.

As previously discussed, early fossils indicating hominin evolution have been discovered both inside and outside of Africa. However, most of the fossil evidence found in China, Java (a major island in Indonesia), the Middle East, Europe, and Africa is associated with *Homo erectus*. These finds date to between 1.8 million and 250,000 years ago. In early periods in Africa, *H. erectus* coexisted with other species of earlier hominins such as *H. habilis* and *H. rudolfensis*. One of the most complete finds, known as "Turkana boy," was recovered at the Nariokotome site near Lake Turkana in Kenya. The relatively complete skeleton of an eight-year-old boy about five feet tall is comparable with the size of modern humans today. The skeleton demonstrates that the Turkana boy is definitely human below the neck. The cranium indicates a brain capacity of about 900 cc, which falls into the range of *H. erectus* (Stringer and Andrews 2005).

Anatomically, *H. erectus* fossils represent a major new stage of hominin evolution, especially with respect to brain size. The cranial capacity of *H. erectus* ranges between 895 and 1,040 cc, making the skull size of some of these individuals not much smaller than that of modern humans (Kramer 2002; Stringer and Andrews 2005). This evidence indicates that most of the growth in brain size occurred in the neocortex. The populations of *H. erectus* differed from modern humans in that they had a low, sloping forehead and thick, massive jaws with large teeth.

However, the jaws and teeth were much smaller than those of earlier *Homo* species such as *H. habilis*. From the neck down, their skeletal features are similar to those of modern humans, but their bones are much heavier, indicating a very powerful musculature. During this period of hominin evolution, there appears to be very little anatomical change among the *H. erectus*.

### Migration of *Homo erectus*

Given that the early hominins evolved in Africa, the question arises of how these hominins including *H. erectus* became so widely dispersed throughout the world. The major hypothesis is that as populations increased, a certain percentage migrated into new territories following game animals as they moved out of Africa (Antón, Leonard, and Robertson 2002).

As these populations migrated across continents, they encountered different climates and environments. This movement occurred during a period known as the Pleistocene Epoch, which marked the later stages of what we popularly call the Ice Age. At intervals during this time, huge masses of ice, called glaciers, spread over the northern continents, producing colder climates in the temperate zones such as Europe and northern Asia, and increased rainfall in the tropical areas, creating grasslands and new lakes. *Homo erectus* populations had to adapt to a wide variety of climatic and environmental conditions whether they remained in the tropics, as many did, or migrated to new areas of the world.

### Fire

*Homo erectus* probably could not have survived in the colder climates without the use of fire. The earliest use of fire, however, appears to be in Africa near Lake Turkana in northern Kenya dated at 1.8 mya (Gowlett and Wrangham 2013; Hlubik et al. 2017). Later, fire was also associated with *H. erectus* sites in both Europe and Asia. The use of fire to cook food added an important element to the diet. Cooking food made it more digestible and safer to consume. In addition, fires could be used to keep predators away, enabling *H. erectus* to survive more effectively. It is unclear whether *H. erectus* knew how to make fire (fire begun by lightning or forest fires could have been kept lit), but there is no question that fire was controlled. In some regions, the high frequencies of natural fires may have provided a consistent and reliable access for these hominins (Sandgathe and Berna 2017). Anthropologist Richard Wrangham (2010) suggests that *H. erectus* mastered the use of fire for cooking, enabling more efficient foraging and digesting, resulting in smaller teeth, jaws, and face, freeing energy to develop a larger brain.

### Acheulean Technology

An abundance of stone tools associated with *Homo erectus* indicates a remarkable evolution in technology. This new technology is known as the Acheulean technology, named after the

town of Saint-Acheul, France, where some of the first finds were made. This Acheulean technology is dated at 1.5 mya in Africa, and it persists in Europe long after *H. erectus* becomes extinct.

Like the Oldowan choppers, Acheulean tools were produced by percussion flaking, but they exhibit more complexity. Most characteristic of the Acheulean tool is the hand ax, a sharp, bifacially flaked stone tool shaped like a large almond, which would have been effective for a variety of chopping and cutting tasks. Unlike Oldowan choppers, which consisted of natural cobbles with a few flakes removed, the hand ax was fashioned by removing many flakes to produce a specific form. In other words, the toolmaker had to be able to picture a specific shape in a stone. Late Acheulean tools were produced through a more refined form of percussion flaking, the *baton method*. In this technique, a hammer, or baton, of bone or antler was used to strike off flakes. The baton allowed for more accurate flaking and produced shallower, more delicate flakes than a hammer stone.

## TRANSITION TO *HOMO SAPIENS*

### 2.7 Describe the physical and cultural characteristics of Neandertals.

The fossil evidence demonstrates that there was a gradual evolution of *H. erectus* into an anatomically modern *H. sapiens*. Paleoanthropologists classify varied transitional species that exhibit a mix of characteristics seen in *H. erectus* and *H. sapiens* as archaic *Homo sapiens*. They are represented in fossil finds in sites throughout Europe, England, Africa, Asia, and the Middle East.

The oldest transitional forms discovered, first known from Heidelberg, Germany, have been classified as *Homo heidelbergensis* dated from about 700,000 to 200,000 years ago, but may be linked to another find known as *Homo antecessor* found in Spain that is dated at around 800,000 years ago. These transitional forms may be the ancestors of the archaic *Homo neanderthalensis* and modern humans (Stringer 2012). The Neandertal, or *H. neanderthalensis*, the hominin population that lived in Europe, dates between 430,000 and 24,000 years ago. Because of inconclusive evidence, some paleoanthropologists include this species within our own as *H. sapiens neanderthalensis* (Tattersall 1998; Trinkaus and Shipman 1994).

Physically, all archaic *H. sapiens* populations shared some general characteristics, although distinctive variations existed from region to region. The skeletal evidence suggests that they were short, about five feet, six inches tall, but powerfully built. The hands and feet were wider and thicker than those of modern humans. The skull and face were broad, with a larger jaw, larger teeth, and extremely prominent brow ridges. The Neandertal physique, which is very distinct from that of other archaic *H. sapiens*, has become the model for the stereotype of “cavemen” frequently portrayed in cartoons and other popular entertainment.

This image of a brutish prehistoric creature is misleading. The skull of the Neandertal was large, ranging from 1,200 to 2,000 cc, and could accommodate a brain as large as, or even larger than, that of a modern human. Moreover, recent studies of the Neandertal skull indicate that the structure of the brain was essentially the same as that of modern humans, suggesting similar intellectual capacities.

Possible clues to Neandertals' relatedness to modern humans come from molecular testing of genetic material extracted from Neandertal bones. Though estimates of the separation of the Neandertals and modern humans range from 500,000 years ago, the genetic evidence suggests interbreeding between the two different populations at about 50,000 years ago (Sankararaman et al. 2012). The genetic testing has demonstrated that Neandertal DNA in non-African modern human populations ranges from 1.5 to 4 percent (Hawks 2013; Simonti et al. 2016). Though the Neandertal DNA may have provided immunity from regional pathogens and diseases for modern humans, today it may influence health conditions ranging from allergies to risks of depression (Hawks 2017; Simonti et al. 2016).

Increasing understanding of archaic human populations has been made by the fossil and archaeological identification of the **Denisovans**, or the **Denisova hominins**, a subspecies that was contemporaneous with modern humans and Neandertals (Hawks 2017). These hominin remains are located in Denisova cave in Siberia, Russia. Archaeological data suggest that the site was occupied from over 125,000 years ago up until modern times (Dalton 2010; Hawks 2017; Krause et al. 2010). Archaeological excavations suggest possible occupation by both Neandertals and modern humans. Genetic data gleaned from bones recovered from the site dating to between 30,000 and 48,000 years ago suggest that the Denisovans share a common origin with Neandertals and that they interbred with both Neandertals and anatomically modern humans. Additional study of the genomic data suggests interbreeding with another, unknown human lineage distinct from the Neandertals and modern humans (Hawks 2013; Pennisi 2013). Recently, a new discovery of a Denisovan jawbone on the Tibetan Plateau in a cave in Gansu, China, dated at 160,000 years ago indicates that this hominin was also in Asia (Chen et al. 2019). Discoveries such as these are indicative of the complex history of human interactions and the questions that remain for paleoanthropologists to answer.

### Neandertal Technology: The Middle Paleolithic

The early European archaic *Homo sapiens* who had migrated from Africa were using Acheulean stone tools. However, the stone tool industry associated with Neandertal populations is called the **Mousterian tradition**, named after a rock shelter at Le Moustier, France, where it was first identified. The Mousterian

technology is classified within the period known as the *Middle Paleolithic*, or Middle Stone Age. It shows a remarkable variability compared with earlier technologies and for this reason is distinguished as a Middle Paleolithic industry. Mousterian implements could have been used for cutting, leather working, piercing, food processing, woodworking, hunting, and weapons production (Binford and Binford 1966; Bordes 1968; Hayden 1993). Neandertals also must have been capable of making some type of clothing, or else they would not have been able to survive the cold European climate. In addition, archaeologists have discovered evidence of the extensive occupation of caves and rock shelters, as well as of open-air sites that may have been temporary camps used during the summer months. Archaeological evidence includes the remains of charcoal deposits and charred bones, indicating that, like earlier *Homo erectus*, Neandertals used fire not only for warmth but also for cooking and perhaps for protection against dangerous animals. In Neandertal sites in Spain, France, and Belgium, cut marks on skeletal material indicate evidence for cannibalism (Rougier et al. 2016).

The remains discovered at the Neandertal sites suggest that, like populations of archaic *H. sapiens* in other areas, Neandertals were efficient hunters. They hunted both small and large game, including such extinct creatures as European elephants, giant elk, bison, and huge bears weighing up to 1,500 pounds and standing over twelve feet tall. These bears, related to the Alaskan brown bear, are known as "cave bears" and were formidable prey for Neandertal hunters.

### Neandertal Ritual and Beliefs?

Study of Neandertal sites has also given archaeologists the first hints of activities beyond hunting and gathering and the struggle for subsistence—possible evidence that Neandertals practiced rituals. Regrettably, much of this evidence, portrayed in countless movies, novels, and caricatures, is far more circumstantial than archaeologists would like. Finds that have been examined include both bear bones and Neandertal artifacts.

Despite the romantic appeal of a Neandertal "cave bear cult," however, these interpretations lack the most important thing archaeologists need to glean insights into such complex issues as prehistoric ritual beliefs: clearly documented archaeological context (Chase and Dibble 1987; Trinkaus and Shipman 1993). In the absence of clear associations between the bear bones and the tools, this evidence suggests only that Neandertals visited a cave in which bears may have hibernated and occasionally died. Many of the finds were not excavated by trained archaeologists, and no plans or photographs of the discovery were made at the time of excavation (Rowley-Conwy 1993). Without this information, interpretation of Neandertal ritual remains entirely speculative.

**FIGURE 2.2** Comparisons of Cranial Features of *Homo sapiens*, Neandertals, and *Homo erectus*



*Homo sapiens*



*Homo sapiens neanderthalensis*



*Homo erectus*

*Source:* Courtesy of Christopher DeCorse.

More convincing than the evidence for a bear cult are discoveries suggesting that Neandertals were the first hominins to intentionally bury their dead. Finds at a number of sites—including Shanidar, Iraq; Teshik-Tash, Uzbekistan; La Chapelle-aux-Saints, France; several areas in Spain; Kebara, Israel (Rowley-Conwy 1993; Trinkaus and Shipman 1994)—have been interpreted as burials. Of these finds, the evidence for intentional burial is most compelling at the French and Israeli sites. In both instances, the skeleton of a Neandertal man was found in a pit that seems to be too regular in shape to have been formed naturally. In a recent evaluation of the Neandertal burial at the French site in La Chapelle-aux-Saints, the archaeologists and paleoanthropologists have concluded that this was definitely an intentional burial (Rendu et al. 2014).

Other skeletal evidence indicates that Neandertals cared for individuals with disabilities (Spikins et al. 2018). At the Shanidar site, for example, archaeologists identified the remains of one individual who had suffered a violent blow to the face, leaving him blind; a withered right arm and hand; and possible paralysis caused by deformities in his leg and foot—the results of an accident or a birth defect (Spikins et al. 2018). Despite these disabilities, this individual lived a relatively long life. In an analysis of various sites where health care is evident, it appears that Neandertals provided food sharing and provisioning for others in their social networks, indicating that they had common human emotions regarding suffering and vulnerability in their harsh environments (Spikins et al. 2018). Although no set of ritual beliefs can be inferred on the basis of these finds, they clearly do indicate the growing group communication, social complexity, and awareness that distinguish these hominins.

### Anatomically Modern *Homo sapiens*

Anatomically modern humans—that is, people who physically looked like us—likely evolved from *H. erectus* in Africa between 200,000 and 400,000 years ago. The earliest-possible fossil evidence of anatomically modern humans has been found in Morocco at a cave site known as Jebel Irhoud, dated to 315,000 years ago (Hublin et al. 2017; Richter et al. 2017). Originally thought to be Neandertal, the specimens analyzed by the Max Planck Institute for Evolutionary Anthropology were reclassified as *H. sapiens*. The cranial evidence indicates that the faces are similar to our own, but the braincase is more elongated and different from later *H. sapiens*. The fossil remains were found with flint artifacts that were used for tools, fire, and cooking.

Other fossil remains of anatomically modern *Homo sapiens*, dated to between 130,000 and 70,000 years ago, have been found in eastern and southern Africa (Stringer 2016; Stringer and Andrews 1988, 2005). Anatomically modern human fossils dating to 155,000 years ago have been discovered at Herto in the Middle Awash region of Ethiopia (T. White et al. 2003). In Omo, Ethiopia, two hominin skulls have been classified

as *H. sapiens*. Modern *H. sapiens* did not just evolve in one area of Africa. All of these African fossils and artifacts in different regions represent variation and diversity that were shaped by the various ecological and climatic conditions such as tropical rainforests or savannahs in Africa (Scerri et al. 2018). These paleoanthropological and archaeological finds indicate that anatomically modern *H. sapiens* evolved within a set of interlinked deeply rooted African populations who were widely dispersed. Instead of showing a lineal tree of evolution of *H. sapiens* in Africa, a better metaphor is of a braided rivulet with various streams weaving in and out, intermixing, and resulting in a modern human form (Ackermann, Mackay, and Arnold 2016).

The fossil evidence indicates that there were several migrations of *H. sapiens* out of Africa. Remains of teeth dated to 80,000 to 120,000 years ago in China and an *H. sapiens* jawbone in Israel dated at 200,000 years ago shows these early migrations (Gibbons 2015; Herschkovitz et al. 2018). However, the consensus of most paleoanthropologists today indicates that the major migrations of *H. sapiens* out of Africa appear to be between 60,000 and 10,000 years ago. These modern *H. sapiens* populations migrated to places all over the globe, adapting both physically and culturally to conditions in different regions.

Physically, these modern *H. sapiens* populations were much the same as modern humans. Their fossilized skeletons do not have the heavy, thick bones; large teeth; and prominent brow ridges associated with the Neandertals and other archaic forms. The high, vaulted shape of the skull is modern, and its dimensions are similar to the skulls of modern-day humans (Stringer 2016). From the cold climates of northern Asia to the deserts of Africa, groups of *H. sapiens* shared similar characteristics as part of one species. However, like populations today, these early groups developed different physical traits, such as body size and facial features, as a result of local environmental conditions and selective pressures.

## THE EVOLUTION OF MODERN HOMO SAPIENS

### 2.8 Discuss the three models of evolutionary development of modern humans.

Although paleoanthropologists generally agree that *Homo erectus* evolved into *Homo sapiens*, they disagree about how, where, and when this transition took place. Early interpretations were based on limited information and often emphasized the uniqueness of individual finds. Recent researchers have offered a number of different theories that fall into several overarching models (Stringer 2001, 2014). There is a consensus that anatomically modern humans first evolved in Africa and then spread out to other world areas. However, a variety of competing interpretations continue to be evaluated.

## Multiregional Evolutionary Model

As noted earlier, *Homo erectus* has the widest distribution of any hominin species other than modern humans. According to the **multiregional evolutionary model**, the gradual evolution of *H. erectus* into archaic *H. sapiens* and, finally, modern *H. sapiens* took place in the various parts of Asia, Africa, and Europe at the same time, as illustrated in Figure 2.3a. This model, initially proposed in the 1940s, represented the view many anthropologists had of modern human evolution into the 1980s. Through natural selective pressures and genetic differences, local *H. erectus* populations developed particular traits that varied from region to region; consequently, the variations in physical characteristics noted in modern human populations were deeply rooted in the past (Wolpoff and Caspari 1997, 2002). *Gene flow*—the widespread sharing of genes—between populations in the different regions prevented the evolution of distinct species. The emergence of *H. sapiens* was, therefore, a widespread phenomenon, although different regional populations continued to exhibit distinctive features.

## Replacement Model

A second major paradigm to explain the evolution of modern humans is the **replacement model**, or the single-source model (Stringer 2014; Stringer and Andrews 2005). This model holds that *H. sapiens* evolved in one area of the world first and migrated

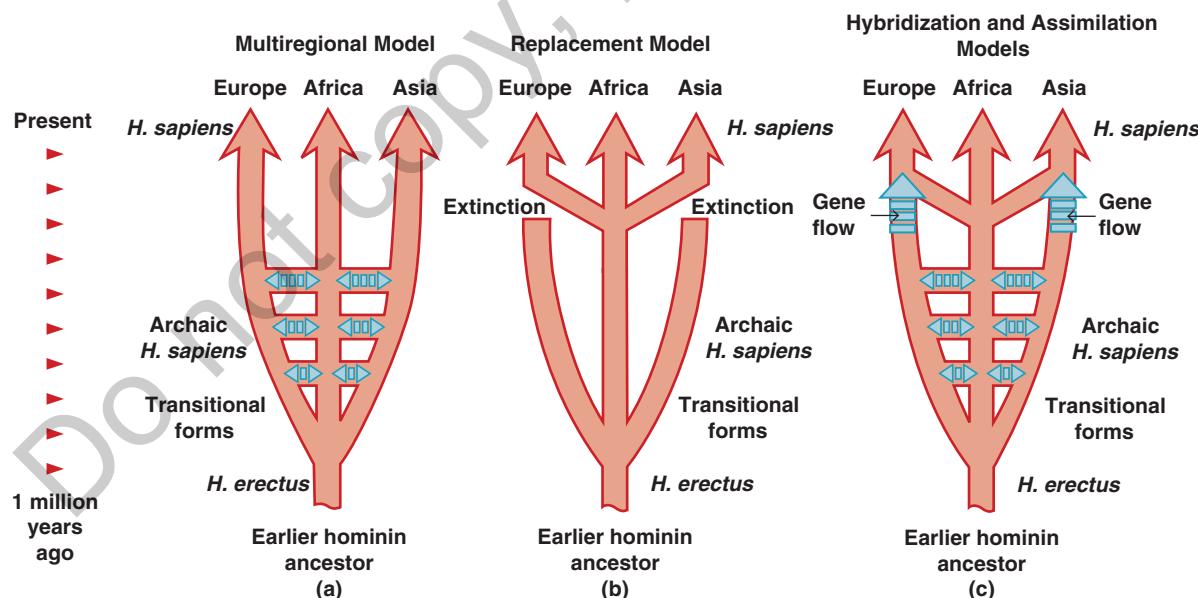
to other regions, as illustrated in Figure 2.3b. It is called a replacement model because it assumes that *H. sapiens* were contemporaries of the earlier *H. erectus* but eventually replaced them. Thus, although the modern and archaic species overlapped in their spans on Earth, they were highly distinctive, genetically different evolutionary lineages. According to the replacement hypothesis, *H. sapiens* populations all descended from a single common ancestral group. In this “Out of Africa” view, after 400,000 years ago, *H. heidelbergensis* gave rise to modern *H. sapiens* in Africa and *H. neanderthalensis* in Europe. However, the Neandertal type became extinct and was replaced by *H. sapiens*.

Some researchers believe that fossil evidence supporting the replacement hypothesis may be found in the homeland of all hominins: Africa. As discussed earlier, fossils of anatomically modern *H. sapiens* are dated to as early as 320,000 years ago in Morocco. These African fossil finds may represent the earliest examples of modern humans found anywhere in the world. Some advocates of the replacement model contend that after evolving in Africa, early *H. sapiens* migrated to other regions, replacing earlier hominin populations that had arrived in those same regions hundreds of thousands of years before.

## Hybridization and Assimilation Models

The processes involved in the emergence of modern humans were likely more complex and encompassed more variables than can be neatly wrapped up in either of these two

**FIGURE 2.3 ■ Contrasting Interpretations of the Emergence of Modern *Homo sapiens***



**Note:** The multiregional evolutionary model (a) suggests regional continuity and the gradual evolution of all *H. erectus* and archaic *H. sapiens* populations into modern humans, with gene flow between populations (here represented by the red arrows) preventing the emergence of distant species. In contrast, supporters of the replacement model (b) see modern humans as evolving in Africa and spreading out, replacing earlier hominin populations. More recent hybridization and assimilation models (c) allow for greater degrees of genetic admixture between *Homo sapiens* and earlier populations of archaic *H. sapiens*.

overarching perspectives. Many more recent interpretations of modern human origins have attempted to reconcile the conflicting aspects of the multiregional and replacement models. Emergent human populations likely incorporated a great deal of physical diversity—as well as behavioral, social, and linguistic differences. Further, it is unlikely that early human migrations, out of Africa and elsewhere, were unidirectional affairs involving the movement of homogeneous populations. Many different migrations via different routes, recolonization of previously occupied territories, and *gene flow* (interbreeding and exchanging genes) with other populations likely took place. Understanding such complexities provides insight into not only the emergence of modern humans, but also the source of the diversity underlying present-day populations.

The newest interpretation can be referred to as the **hybridization and assimilation model** in that it allows for varying degrees of gene flow between *Homo sapiens* and earlier populations of archaic *H. sapiens* such as the recent research on DNA and Neandertals and Denisovans demonstrates. In this hybridization and assimilation hypothesis (Figure 2.3c), anatomically modern *H. sapiens* emerged in Africa first, over 100,000 years ago, and then migrated outward into other world areas. As a result of interbreeding, anatomically modern humans hybridized with earlier archaic populations, eventually replacing them. In fact, fossil evidence from the Near East, as well as Europe and East Asia, indicates that different hominin species overlapped in time and space. These interpretations underscore a greater amount of gene flow than the replacement model allows. This model may more correctly represent the complex and gradual nature of the processes represented (Ackermann, Mackay, and Arnold 2016).

## MODERN HOMO SAPIENS CULTURE: THE UPPER PALEOLITHIC

### 2.9 Describe the cultural features of the Upper Paleolithic.

In general, the material artifacts associated with modern *Homo sapiens* populations become increasingly complex. Throughout Africa, the Middle East, Asia, the Americas, and Australia, complicated and elaborate technologies and other culturally decorative artifacts are found in abundance. Recent archaeological sites dated at about 320,000 years old in southern Kenya indicate fairly sophisticated stone tools made from black volcanic glass known as obsidian and colored rocks made with pigments are found (Deino et al. 2018). Although no *H. sapiens* fossil remains are associated with these artifacts, they do represent innovative techniques. This creative explosion in technology and symbolism is also correlated with dramatic shifts in climatic changes in this East African region that may have led to these innovative adaptations.

A major period known as the **Upper Paleolithic** (the term *Paleolithic* refers to “Old Stone Age,” whereas *Upper* indicates the later part of this period) is usually dated between 40,000 and 10,000 years ago, approximately. However, the basis for the Upper Paleolithic technological developments extends back into the early phases of modern *Homo sapiens*. As mentioned above, in Morocco, the first major modern *Homo sapiens* dated at 315,000 years ago were associated with sophisticated flake technologies. In addition, as seen in the eastern African sites previously mentioned, dated at 320,000 years ago, many complex technologies and new tools were on the increase and were exchanged widely throughout Africa.

However, after 50,000 years ago, the technological and social innovations of the Upper Paleolithic represent another creative explosion in technology. Innovation of this magnitude required a highly developed capacity for the accumulation and transmission of knowledge, likely indicating that the inhabitants had developed efficient subsistence strategies that allowed free time for experimentation and innovation (Rossano 2010).

### Upper Paleolithic Tools

These different Upper Paleolithic traditions encompass a tremendous amount of variation in stone tool types. The most important technological shift in stone tool production involved the making of blades: long, narrow flakes that could be used to produce many types of knives, harpoons, and spear points. Among the most striking examples of Upper Paleolithic percussion flaking are Solutrean projectiles, dated to 20,000 years ago. These implements, often several inches long, probably functioned as spear points. Yet, the flaking is so delicate and the points so sharp that it is difficult to imagine them fastened to the end of a spear. It has, in fact, been suggested that they were made as works of art, not tools for everyday use. In addition, specialized stone tools, including borers, or drills, and burins, chisel-like tools for working bone or ivory, were produced. Tools such as these would have aided in the manufacture of the bone, antler, and ivory artifacts that become increasingly common during the Upper Paleolithic. A particularly important piece of equipment that appeared during this time period is the spear-thrower (or *atlatl*, the Aztec word for this tool), a piece of wood or ivory that increased the power of the hunter’s arm. The increased leverage provided by the spear-thrower enabled Upper Paleolithic hunters to hurl projectiles much faster than they could otherwise.

Another category of artifact that became common is the **composite tool**, an implement fashioned from several different materials. An example of a composite tool is the harpoon, which might consist of a wooden shaft that is slotted for the insertion of sharp stone flakes. Also discovered at Upper Paleolithic sites were needles for sewing clothing and fibers for making rope, nets, trapping equipment, and many other artifacts.

Courtesy of Peter Turchin



Reconstruction of an Upper Paleolithic tent dwelling made from mammoth bones and skin. Found in Ukraine.

### Upper Paleolithic Shelters

Upper Paleolithic sites have produced numerous indications of shelters, some of which were quite elaborate, in many parts of the world. Some of the more spectacular were found at a 15,000-year-old site at Mezhirich in Ukraine. This site contained five shelters constructed of bones from mammoths, an extinct species of elephant (Gladkih, Korneitz, and Seffer 1984). The mammoth's jaws were used as the base, and the ribs, tusks, and other bones were used for the sides. The interiors contained work areas, hearths, and accumulations of artifacts, suggesting that they were inhabited for long periods. Storage pits were located in areas between the structures. This settlement may have been occupied by as many as fifty people.

### Variations in Upper Paleolithic Technologies

Variations in tools found in different regions suggest that early humans had developed specialized technologies suited to particular environments. These variations also reflect the fact that different regions contained different forms of stone from which tools could be manufactured. In addition, regional differences may also reflect variations in culture, ethnicity, and individual expression. Archaeologist James Sackett (1982), who has studied the classic Middle and Upper Paleolithic finds of France, notes that even tools that may have served the same function exhibit a great deal of variation. Many Upper Paleolithic artisans made their stone tools in distinctive styles that varied from region to region. Today, we often associate distinctive dress, decoration, and housing with different ethnic groups. To archaeologists, expressions of ethnic identity preserved in material remains are extremely important. Frequently, we refer to archaeological cultures, which are defined on the basis of the distinctive artifacts they left behind. Stone tools may provide the first indications of ethnic and cultural divisions in human populations.

Expressive elements are also seen in other Upper Paleolithic artifacts. In comparison with the Middle Paleolithic, there are more nonutilitarian objects, including items for personal adornment (Rossano 2010). Some of these artifacts were obtained from distant sources, providing evidence of the development of trade networks.

### Upper Paleolithic Subsistence and Social Organization

Middle and Upper Paleolithic societies employed many of the same subsistence strategies as Lower Paleolithic groups. The Upper Paleolithic technology indicates that early modern *Homo sapiens* were efficient hunters. Many sites contain large heaps of bones of mammoths and other animals. In addition, piles of animal bones have been found at the bottoms of high cliffs, which suggests that *H. sapiens* hunters stampeded the animals off cliffs to be killed and butchered by hunters waiting below. Archaeologists have also found remains of traps used by Upper Paleolithic hunters to snare animals.

Upper Paleolithic people also gathered plants to supplement their food resources. Plants were probably used for both nutritional and medicinal purposes. However, the generally small size of Upper Paleolithic living areas and the limited amount of plant remains recovered from archaeological sites provide only an incomplete view of diet during that period.

### Social Organization

One way to develop hypotheses about the lifestyle and social organization of prehistoric people is to study the social organization of contemporary groups with similar subsistence strategies (D. T. Price and Brown 1985). Anthropologists recognize, however, the limitations of this approach. Present-day hunters and gatherers occupy marginal areas such as the dry desert regions of southern Africa (see Chapter 8). In contrast, Paleolithic foraging populations resided in all types of environments, many of which were rich in food resources. Most likely, these abundant food resources enabled Paleolithic foragers to gather adequate food supplies without expending excessive amounts of energy.

Contemporary foraging societies, with their relatively small groups, low population density, highly nomadic subsistence strategies, and loosely defined territorial boundaries, have social organizations that serve to tie kin together and foster unity within and among groups. In the past, these flexible social relationships may have enabled foragers to overcome ecological and organizational problems.

Whether ethnographic data on the social organization of “modern” foragers can instruct us on the type of social systems Paleolithic foragers had is, as yet, an open question. Some archaeological studies suggest that the size of domestic groups of Paleolithic societies corresponds to that of contemporary foragers (Campbell 1987; Pfeiffer 1985), but other anthropologists



Upper Paleolithic Venus figurine.

suggest that ethnographic models underestimate the diversity of prehistoric hunting and gathering adaptations. They also point out that modern hunter-gatherer societies may have been greatly modified through recent encounters with the outside world. (We return to this topic in Chapters 8 and 14.)

### The Upper Paleolithic in Africa and Europe

Changes seen in the Upper Paleolithic period in both Africa and Europe are indicative of developments in much of the world. In addition to their other technological accomplishments, the Upper Paleolithic peoples of both Africa and Europe (and elsewhere, as seen later) produced an impressive array of artistic creations. In Africa, large naturalistic paintings have been dated at 28,000 years ago (Philipson 1993). Painting techniques such as the use of ochre appear to have diffused from Africa to Europe during the migrations of *H. sapiens* (S. Wolf et al. 2018). Many other Upper Paleolithic artifacts, such as the Venus fertility goddesses (female figurines with large hips, ample breasts, and abdomens indicating fertility), are found throughout Europe.

As in Africa, mural paintings found in the caves of Spain and France, such as those of the Lascaux Caves, are magnificent abstract and naturalistic paintings of animals and sometimes of humans dressed in the hides of animals. These murals might have been intended to celebrate a successful hunt or to ensure a better future. That some murals are located deep within underground caves may indicate that this art held profound spiritual and religious significance for its creators. What could be a more awe-inspiring site for a religious celebration or initiation ceremony than a dark underground chamber with beautiful paintings? On the other hand, some art may in essence be “art for art’s sake,” painted solely for enjoyment (Halverson 1987).

### Migration of Upper Paleolithic Humans

Upper Paleolithic hunters and gatherers developed specialized technologies that helped them adapt to different environments in ways their precursors could not have. The remarkable abilities of *Homo sapiens* to exploit such a wide variety of environments enabled them to increase their populations, leading to modern human habitation across the globe. During the Upper Paleolithic, *H. sapiens* migrated throughout the world, including North and South America and Australia, continents that had previously been unoccupied by hominins.

The movement of modern *H. sapiens* populations into new areas was aided by changes in world climatic conditions during the past 12,000 years. This period encompasses the later part of the Pleistocene, or Ice Age, when climatic conditions were much cooler and moister than they are now. Northern Europe, Asia, and North America were covered by glaciers, which were extensions of the polar ice caps. The vast amount of water frozen in these glaciers lowered world sea levels by hundreds of feet, exposing vast tracts of land, known as continental shelves, that were previously (and are currently) beneath the sea. Many world areas that are today surrounded by water were at that time connected to other areas.

### Upper Paleolithic Hunters in America

There is a consensus among archaeologists that the first humans came to the Western Hemisphere from Siberia over what is now the Bering Strait into the area of modern Alaska. There was a land bridge connecting Siberia and Alaska between 75,000 and 11,500 years ago. There were several migrations of people from Asia across this Beringia land bridge. Relatively ice-free coastal zones may also have allowed early migrants to use watercraft to move along the coast of the Americas (Bulbeck 2007).

The Asian origin of Native Americans is supported by several lines of evidence, including physical similarities such as blood type, tooth shape, and DNA comparisons between Asian and Native American populations. In addition, studies of the languages and artifacts discovered in both areas indicate a common origin.

Most archaeologists and paleoanthropologists estimate that migration into the Americas extends back to about 40,000 years ago. The most recent artifacts on cut-bone marks on animal bones at a site known as the Bluefish Caves in Yukon, Canada, near the U.S.-Alaska border is dated at 24,000 years ago (Bourgeon, Burke, and Higham 2017). The Bluefish Caves site indicates that this population of humans had come from Siberian Asia and came across Beringia and became isolated until about 16,000 years ago.

Other artifacts dated from a site in Chile and other South American sites indicate that there were very early dates for settlement of the Americas (Carr et al. 1996; Dillehay 1997a, 1997b; Goodyear 1999; Wheat 2012). Eventually, these early Native American peoples, known as *Paleo-Indians*, populated most of what is known today as the United States, Canada, and Central and South America. A significant site has been discovered deep in the Brazilian Amazon by a team of archaeologists led by Anna C. Roosevelt (2013). Excavations uncovered not only stone weapons, but also some of the earliest rock paintings dated in the Americas. These Paleo-Indians were settling in this lowland Amazon area at about 13,000 years ago. Discoveries in South American sites challenged the traditional theories regarding the settlement of Paleo-Indians in the Americas. These Paleo-Indians were living 5,000 miles to the south of North America and settled in a completely different lowland tropical environment. They were not big-game hunters like their northern neighbors, but rather they were fishing, capturing birds and turtles in a much different habitat. However, all of the Paleo-Indians were producing a complex set of tools and subsistence hunting-gathering strategies that enabled them to adapt to many different environments of Pleistocene America.

## Physical Variation in Modern Humans

Modern *Homo sapiens* populations migrated throughout the world, adjusting to different environmental conditions. As different populations settled in different environments, they developed certain variations in physical differences among groups within the species. Variations occur with respect to body size, eye color, hair texture and color, shape of lips and nose, blood type, and eyelid form. In certain cases, these characteristics are related to the types of selective pressures that existed in a particular environment; in other cases, they are simply the result of physical isolation in certain areas during past eras.

## SKIN COLOR

### 2.10 Discuss the factors of natural selection that influence skin color differences in modern humans

One of the most obvious differences in modern humans is skin color. Skin pigmentation has long been used as the primary basis for classifying race (see Chapter 16). In general usage, the

term *race* refers to the physical characteristics of a population that are based on common descent. However, the means and methods of such classifications are arbitrary and problematic.

One eighteenth-century approach placed all peoples in one of four racial categories: Europeans (white), Americans (red), Asiatics (yellow), and Africans (black). These early attempts to classify humans by skin color led to stereotypes among Europeans regarding different human populations.

More recent classifications, based on scientific knowledge of genetics, evolution, and geography, sometimes have included hundreds of racial categories (Garn 1971). However, modern physical anthropologists have concluded that any system of racial classification is too rigid and inflexible to deal with the actual dynamics of population movement, genetic change, intermarriage, and other conditions affecting the physical characteristics of a population (MacEachern 2012; Scupin 2012a; Templeton 1998).

Study of modern human variation does, however, provide insight into the evolutionary past of human populations and adaptations to varied environments. For example, increased melanin in the skin, resulting in dark pigmentation, provided an adaptive advantage in tropical environments. It provides protection from ultraviolet radiation, which can cause sunburn, sunstroke, and skin cancers such as melanoma. In addition, large amounts of melanin aid in preserving the amount of vitamin B complex needed for successful reproduction of healthy infants (Jablonski 2012; Jablonski and Chaplin 2000).

A recent genetic study of skin color among various African populations indicates that both light and dark skin have ancient origins (Crawford et al. 2017). This study indicates that both light and dark skin were introduced by African populations who migrated to other areas of the world including parts of Asia and Europe. Our early hominin ancestors had lighter skin pigmentation comparable to other primates. But as populations moved into the open savannah regions where there was more direct sunlight, darker skin was necessary to protect against the harmful effects of ultraviolet radiation.

Additionally, there were other reasons for skin color adaptations. Folate, a member of the vitamin B complex, is essential for normal fetal development. Low folate levels in mothers have been correlated with embryonic defects, such as spina bifida and anencephaly (the absence of a full brain or spinal cord). Even an hour of exposure to intense sunlight is sufficient to reduce folate levels by half in light-skinned individuals. As *Homo sapiens* evolved in the tropical equatorial zones, darker skin pigmentation was likely highly adaptive (Jablonski 2012).

But later, as populations moved into more temperate regions with less sunlight, other selective pressures produced lighter skin pigmentation. The genes for light skin color among Europeans arose about 29,000 years ago (Crawford et al. 2017). The human need for vitamin D may have played

an important role. Vitamin D helps the body absorb calcium and deposit it in bones, an important function, especially in fast-growing embryos. Insufficiency of vitamin D can result in rickets, a disease that causes abnormal growth of bones. People living in equatorial regions with ample exposure to direct ultraviolet radiation from the Sun, which stimulates the production of vitamin D, would be able to have dark skin coloration. In contrast, people who had migrated to cloudy northern climates would have been disadvantaged in obtaining enough direct ultraviolet radiation to get enough vitamin D. The fossil record indicates that some Neandertals in northern Europe had rickets (Boaz and Almquist 1997). Thus, over time, natural selection would have favored the development of a lighter-skinned population among *H. sapiens* groups in these northern regions.

Physical anthropologists have found that within the indigenous native populations of the world, the weaker the ultraviolet light, the fairer the skin, and the stronger the ultraviolet light, the darker the skin (Holden 2000; Jablonski 2004, 2012; Jablonski and Chaplin 2000). These observations, along with other data from a variety of studies, indicate that environmental conditions were important in selecting for adaptations in skin coloration in different regions of the world (Relethford 2013; Mukhopadhyay, Henze, and Moses 2014). It must be emphasized that these physical variations among modern *H. sapiens* populations are only “skin deep.” In fact, geneticists believe that only a



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Variation in skin pigmentation among humans reflects adaptations to Paleolithic environments with different amounts and intensities of sunlight.

few genes out of between 20,000 and 25,000 code for skin color. Theories claiming the supposed superiority of certain racial groups over others have no scientific basis. Except for general similarities in color and body size, individuals in any given population differ widely from one another in respect to longevity, vitality, athletic ability, intelligence, and other personal characteristics. All populations throughout the world produce individuals who differ widely in their physical and mental abilities. Racism or ethnic prejudice based on the belief in the superiority or inferiority of a particular group is unjustifiable, not only morally but also scientifically.

## SUMMARY AND REVIEW OF LEARNING OBJECTIVES

### **2.1 Explain how cosmologies regarding human origins differ from the scientific view of evolution.**

Cosmologies are conceptual frameworks that present the universe (the *cosmos*) as an orderly system. They often include explanations of human origins and the place of humankind in the universe. Cosmological explanations frequently involve divine or supernatural forces that are, by their nature, impossible for human beings to observe. We accept them and believe in them, on the basis of faith. Scientific theories of evolution, in contrast, are derived from the belief that the universe operates according to regular processes that can be observed. The scientific method is not a rigid framework that provides indisputable answers. Instead, scientific theories are propositions that can be evaluated by future testing and observation. Acceptance of the theory of evolution is based on observations in many areas of geology, paleontology, and biology.

### **2.2 Discuss how the scientific revolution provided the context for the theory of evolution.**

In Europe during the Renaissance (c. A.D. 1450), scientific discoveries began to influence conceptions about the age of the Earth and humanity’s relationship to the rest of the universe. Copernicus and Galileo presented the novel idea that the Earth is just one of many planets revolving around the Sun, rather than the center of the universe, as had traditionally been believed. As this idea became accepted, humans could no longer view themselves and their planet as the center of the universe. This shift in cosmological thinking set the stage for entirely new views of humanity’s links to the rest of the natural world. New developments in the geological sciences began to expand radically the scientific estimates of the age of the Earth. These and other scientific discoveries in astronomy, biology, chemistry, mathematics, and other disciplines dramatically transformed Western thought. The revolutionary scientific research by Charles Robert Darwin

(1809–1882) and Alfred Russel Wallace (1823–1913) independently identified natural selection as a key mechanism for explaining change in species over time.

### 2.3 Explain how natural selection works.

Variation within species and reproductive success are the basis of natural selection. Certain individuals in a species may be born with particular characteristics or traits that make them better able to survive. For example, certain plants within a species may naturally produce more seeds than others, or some frogs in a single population may have coloring that blends in with the environment better than others, making them less likely to be eaten by predators. With these advantageous characteristics, these individuals are more likely to survive to reproduce and, subsequently, pass on these traits to their offspring. Darwin and Wallace called this process natural selection because nature, or the demands of the environment, determines which individuals (and, therefore, which traits) survive. This process, repeated countless times over millions of years, is the means by which species change or evolve over time.

### 2.4 Describe how early hominins are different from other primates.

Hominins, the family of primates that includes the direct ancestors of humans, share certain subtle features in their teeth, jaws, and brains. However, by far the major characteristic that identifies them as a distinct group is the structural anatomy needed for bipedalism, the ability to walk erect on two legs. Bipedalism is not a characteristic of modern apes, such as chimpanzees and gorillas, which can stand upright but do most of their walking on four limbs.

### 2.5 Discuss how *Homo habilis*, *Homo rudolfensis*, *Homo floresiensis*, and *Homo naledi* differ from australopithecines.

The early genus *Homo* includes a variety of different species including *Homo habilis*, *Homo rudolfensis*, *Homo floresiensis*, and *Homo naledi* as multiple overlapping species. The average size of the skull of *H. habilis* is 640 cc, indicating a much larger brain than that of the australopithecines. However, *H. habilis* fossils indicate that this creature had some apelike features such as climbing abilities aside from upright bipedalism. The *H. rudolfensis* skull had a cranial capacity of 775 cc, considerably larger than *H. habilis*. *H. floresiensis* had a small brain with a cranial capacity of 380 cc, in the range of chimpanzees or early australopithecines. The height of *H. floresiensis* is estimated at three feet, six inches. The *H. naledi* cranium ranges from 460 cc to 565 cc. The cranial, dental, and postcranial remains consist of both humanlike characteristics and australopithecine traits.

### 2.6 Describe the cultural characteristics of *Homo erectus*.

*Homo erectus* is dated between 1.8 million and 250,000 years ago. *Homo erectus* migrated outside of Africa to reach areas of Europe and Asia. The fossil evidence for *Homo erectus* is associated with the first usage of fire by hominins. In addition, an abundance of stone tools is associated with *Homo erectus* that indicates a remarkable evolution in technology. This new technology is known as the Acheulean technology. Acheulean tools were produced by percussion flaking and exhibit more complexity than earlier stone tools. Most characteristic of the Acheulean technology is the hand ax, a sharp, bifacially flaked stone tool shaped like a large almond, which would have been effective for a variety of chopping and cutting tasks.

### 2.7 Describe the physical and cultural characteristics of Neandertals.

The skull and face of Neandertals were broad, with a large jaw, large teeth, and an extremely prominent brow ridge. The Neandertal physique, which is very distinct from that of other archaic *H. sapiens*, has become the model for the stereotype of “cavemen” frequently portrayed in cartoons and other popular entertainment. This image of a brutish prehistoric creature is misleading. The skull of the Neandertal was large, ranging from 1,200 to 2,000 cc, and could accommodate a brain as large as, or even larger than, that of a modern human. Moreover, recent studies of the Neandertal skull indicate that the structure of the brain was essentially the same as that of modern humans, suggesting similar intellectual capacities.

The stone tool industry associated with Neandertal populations is called the Mousterian tradition. It shows a remarkable variability compared with earlier technologies. Mousterian implements could have been used for cutting, leather working, piercing, food processing, woodworking, hunting, and weapons production. Archaeological evidence includes the remains of charcoal deposits and charred bones, indicating that, like earlier *Homo erectus*, Neandertals used fire not only for warmth but also for cooking and perhaps for protection against dangerous animals. The Mousterian technology is classified within the period known as the *Middle Paleolithic*, or Middle Stone Age.

Despite the romantic appeal of a Neandertal religion and rituals, archaeologists have not found convincing evidence for these ideas. However, Neandertals were the first hominins to intentionally bury their dead. Although no set of ritual beliefs can be inferred on the basis of these finds, they clearly do indicate the growing group communication, social complexity, and awareness that distinguish humans.

## 2.8 Discuss the three models of evolutionary development of modern humans.

Paleoanthropologists and geneticists are trying to determine the evolutionary relationships of archaic and anatomically modern *H. sapiens*. One model known as the multiregional model is based on fossil evidence from different regions of the world. This multiregional model suggests that *Homo erectus* evolved into modern humans in various regions of the world, but shared genes resulting in one species of modern *Homo sapiens*. Another recent hypothesis known as the replacement model is based on genetic data from modern females that indicates an ancestral line in Africa dating to about 200,000 years ago. The replacement model is also based on fossil evidence from East Africa. One other model known as the hybridization and assimilation model offers a more sophisticated approach to both the fossil and genetic evidence. In this hybridization and assimilation hypothesis, anatomically modern *H. sapiens* emerged in Africa first, over 100,000 years ago, and then migrated outward into other world areas. As a result of interbreeding, anatomically modern humans hybridized with earlier archaic populations, eventually replacing them. In fact, fossil evidence from the Near East, as well as Europe and East Asia, indicates that different hominin species overlapped

in time and space. These interpretations underscore a greater amount of gene flow than the replacement model allows. This model may more correctly represent the complex and gradual nature of the processes represented.

## 2.9 Describe the cultural features of the Upper Paleolithic.

Anatomically modern *H. sapiens* are dated to as early as 320,000 years ago. The technology of modern *H. sapiens* is referred to as the Upper Paleolithic. Many different types of specialized tools were developed in different environments in the Upper Paleolithic. In addition, cave paintings, sculpture, and engravings are associated with this period.

## 2.10 Discuss the factors of natural selection that influence skin color differences in modern humans.

As modern humans adjusted to different environments, natural selection continued to play a role in determining physical characteristics. For example, variations in skin pigmentation reflect adaptations to environments with different amounts and intensities of sunlight. However, modern scientific evidence demonstrates that skin color does not correspond to any difference in the mental capacities of any population.

### KEY TERMS

bipedalism, p. 24

composite tool, p. 35

cosmologies, p. 20

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