A New Kind of Ape

14

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The standard uniform for paleontologists is casual. T-shirts, cutoffs, and floppy old hats are common sights around most fossil digs. But in a Spanish cave called El Sidrón, the dress code is decidedly more formal. Fossil hunters regularly suit up in white coveralls, surgical masks, and sterile gloves. And rather than ordinary rock hammers and chisels, the paleontologists at El Sidrón use sterilized blades to dig at the bones, which they quickly put into a freezer. They look less like fossil hunters than characters out of a science fiction movie.

There is, in fact, a science fiction quality to what the researchers are up to: they want to read the genes of an extinct kind of human whose bones lie in the cave. The bones were discovered in 1994 by cave explorers. When the police first came to the cave, they initially assumed the remains belonged to people killed during the Spanish Civil War in the 1930s. But it soon became clear that the bones were much older—in fact, they were 48,000 years old. And instead of belonging to humans like ourselves,

FIGURE 14.1
Researchers excavating in a cave in Spain have discovered fragments of DNA in 48,000-year-old Neanderthal fossils. They are comparing the genes to ours to gain clues about how human behavior evolved.

they belonged to Neanderthals, a group of hominins that vanished 28,000 years ago (Lalueza-Fox et al. 2012).

Scientists have known about Neanderthals since 1863, when their remains were first discovered in the Neander Valley in Germany. (*Thal* means "valley" in German.) Since then, researchers have found dozens of Neanderthal fossil sites, where they've found not just bones but also tools and other traces of Neanderthal behavior. But in the late 1990s, Svante Pääbo, a geneticist at the Max Planck Institute for Evolutionary Anthropology, pioneered a new way to study Neanderthals: by extracting and analyzing their DNA.

DNA normally breaks down when an organism dies, but under certain conditions, its fragments can survive for tens of thousands of years. Pääbo and his colleagues discovered that some Neanderthal fossils sitting in museums still contained traces of DNA. Even the bones that had been unearthed in 1863 turned out to have genetic material. To find more DNA, the scientists developed new methods for extracting DNA from bones freshly dug up from the ground. To succeed at this audacious task, they have to take every possible precaution to ensure that not even a flake of their skin or a drop of sweat contaminates the fossils with their own DNA.

The precautions start with the masks and suits at places like El Sidrón. But they don't stop there. Researchers ship the frozen remains to Pääbo's ultraclean laboratory in Leipzig. His research team grinds the bones into a powder and gradually removes all the minerals and organic matter until only DNA is left. Then they capture the fragments of DNA and analyze the sequences. In 1997, Pääbo and his colleagues published the sequence of their first sample of Neanderthal DNA. It was only 379 base pairs of mitochondrial DNA—a tiny fraction of the hominin's genes. But in 2010, they unveiled the draft genome of Neanderthals, made up of more than 4 billion nucleotides drawn from material from three different individuals (Greene et al. 2010).

The resurrection of an extinct genome allows scientists to understand these enigmatic people like never before. They are getting a better picture of what Neanderthals looked like, and how their physiology was adaptive for a demanding life hunting big animals. But understanding the Neanderthal genome has another power that's just as important: it allows us to learn things about ourselves.

Neanderthals could hunt elephants and rhinoceroses. They could fashion sophisticated stone tools. They were moved to bury their dead. But the remains of Neanderthals suggest that they couldn't paint a picture. They didn't trade tools over long distances, perhaps because they lacked social skills. In some crucial ways, Neanderthals were different from us. The stages of human evolution that gave us language, symbolic thought, and many other faculties we think make us uniquely human unfolded only after our ancestors split off from the Neanderthals. And now scientists can compare the Neanderthal genome and the genome of living humans to find the mutations that made those adaptations possible.

Humans are but one of millions of species alive on Earth today. Each species has its own intriguing evolutionary history, shaped by a vast number of forces. But when we humans look at the history of life, we can't help being obsessed by how our own species came to be. In this chapter, we'll look at the latest consensus about how humans evolved. We've already encountered fragments of this narrative in previous chapters. Here we will synthesize many lines of evidence—from fossils to genomes—to discover our own story.

An Origin among the Apes

When the eighteenth-century naturalist Carl Linnaeus organized all living things into a single classification system, he decided to put humans in the order Primates, along with apes, monkeys, and other species. Linnaeus recognized that humans and other primates shared a number of anatomical traits, from their forward-facing eyes to their gripping thumbs. He made his decision despite knowing it would be a controversial one. "It is not pleasing to me that I must place humans among the primates," he wrote in a letter to a fellow naturalist in 1747, "but I desperately seek from you and from the whole world a general difference between men and simians from the principles of Natural History. I certainly know of none. If only someone might tell me one!" (Linneaus 1747).

In his 1871 book *The Descent of Man,* Darwin argued that the similarities between primates and humans were evidence that they have a common ancestor. He noted that within the primate order, apes are most similar to humans—they are large bodied, have relatively big brains for their bodies, and have a vestige of a tail just like we do. He argued that apes were therefore our closest primate relatives.

Darwin didn't know it then, but our DNA confirms our primate heritage. Mark Springer, an evolutionary biologist at the University of California at Riverside, and his colleagues published the most detailed molecular phylogeny of primates to date in 2012—an evolutionary tree joining 367 out of the 450 estimated species of primates alive today (Springer et al. 2012). By comparing the mutations in each lineage, they could use a molecular clock to estimate the timing of primate evolution. As **FIGURE 14.2** shows, they found that the common ancestor of all living primates lived about 68 million years ago.

The primates then branched into their two main lineages. One lineage includes lemurs, found only on Madagascar, and the other includes small tropi-

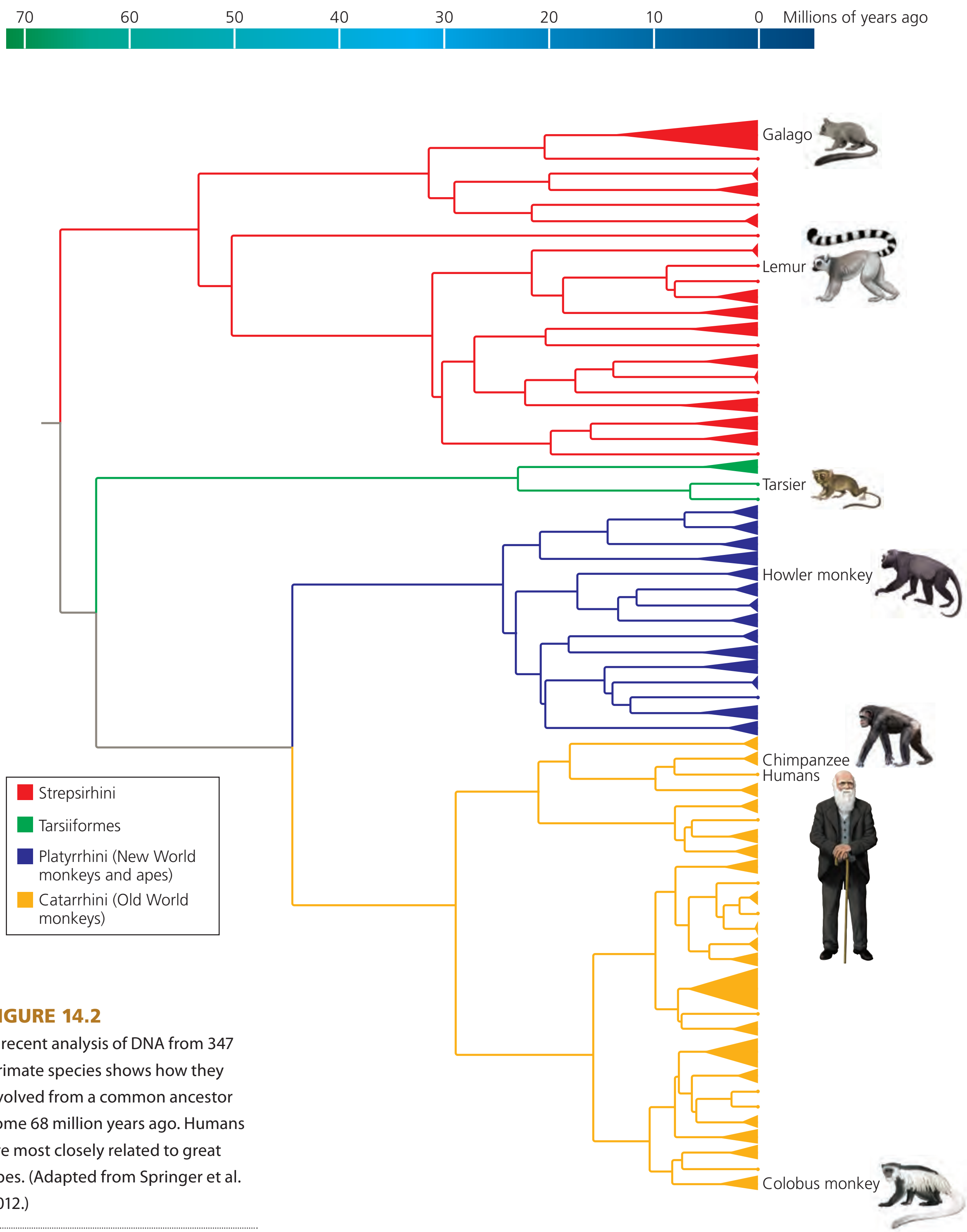

FIGURE 14.2

A recent analysis of DNA from 347 primate species shows how they evolved from a common ancestor some 68 million years ago. Humans are most closely related to great apes. (Adapted from Springer et al. 2012.)

cal primates such as galagos and lorises. The other branch split into new lineages as well. About 40 million years ago, the ancestors of New World monkeys split off from the monkeys of the Old World and the apes. The apes and Old World Monkeys diverged about 30 million years ago. Our own lineage—the hominins—branched off from the ancestors of chimpanzees about 7 million years ago. As with all molecular phylogenies, Springer's primate tree has a range of possible dates for each node. For the human-chimpanzee split, for example, their mean estimate is 6.66 million years ago, with a likely range of between 4.74 and 9.5 million years. As we'll see, that range is a good fit for the fossil record.

Walking into a New Kind of Life

By necessity, Springer and his colleagues could compare only living primates. Ancient DNA survives in appreciable amounts for only tens of thousands of years, not millions. To gain further clues to primate evolution, paleontologists search for extinct species. The earliest primate fossils were tiny, long-tailed creatures that lived in the trees. Starting about 20 million years ago, the fossil record reveals the earliest fossil apes. Found across much of the Old World, these medium- to large-bodied creatures lost their tails; but they still had flexible, strong hands and feet that they could use to grip tree branches (**FIGURE 14.3**).

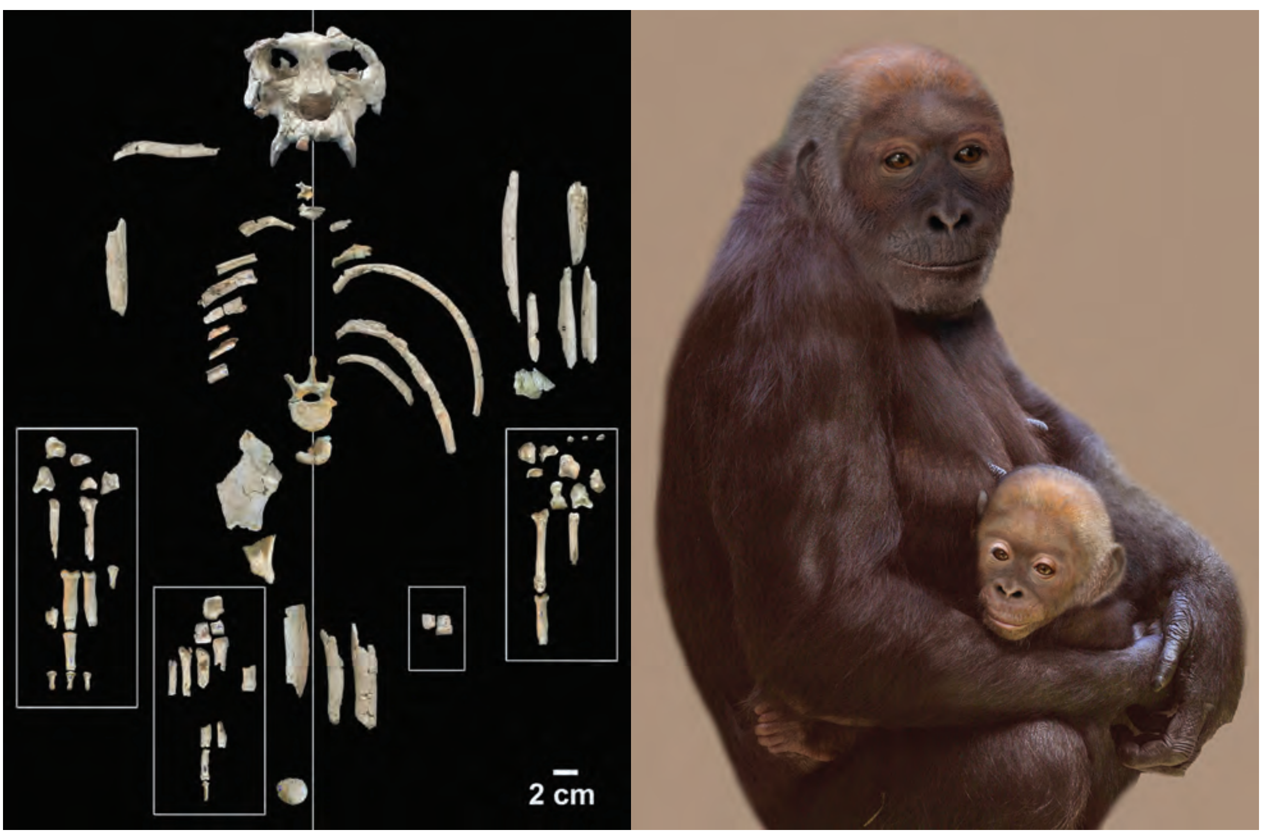

FIGURE 14.3

Pierolapithecus was a species of ape that lived in Spain 13 million years ago. It was closely related to the common ancestor of humans and other living apes. Like apes today, it lacks the tail found on most monkeys and other primates.

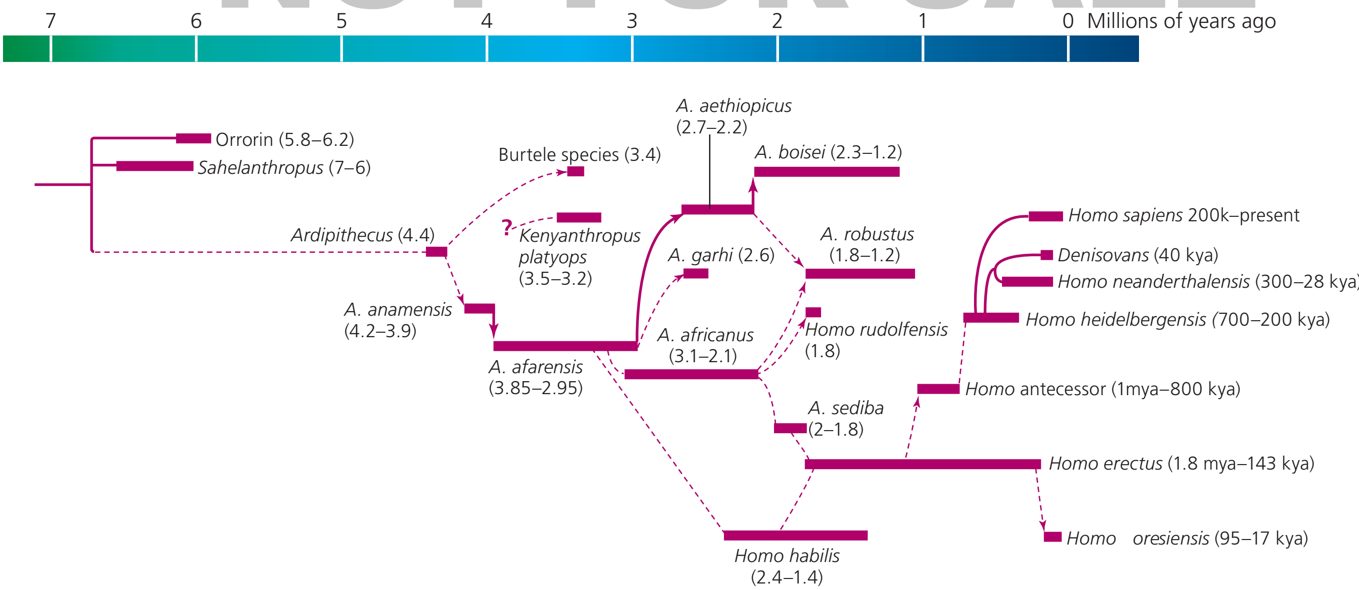

FIGURE 14.4

The hominin fossil record continues to grow. It remains challenging to determine which species are most closely related to each other. This chart shows the current consensus—solid lines show well-supported links, while dotted ones are more contentious. (Adapted from Harmon 2013.)

Over time, many of the early ape lineages became extinct. In Europe the apes disappeared completely, while in Asia a few species survived (gibbons and orangutans still cling to existence there today). In Africa, a greater diversity of apes survived. And it's from these African apes that our own lineage—known as hominins—emerged.

In Chapter 4, we examined some of the best-understood hominins to see how they were related to one another (**FIGURE 14.4**). The full fossil record of hominins is much richer, but also more challenging to interpret. One species is known only from part of its foot, another only from fragments of its skull. These fossils usually contain enough information for paleoanthropologists to be certain that they belonged to hominins and not to some other ape. But they have different views about which hominins are most closely related to which others. Figure 14.4 shows the current state of our understanding of the fossil record—an understanding that improves with each new discovery.

Despite these uncertainties, some important patterns do emerge from the hominin fossil record—patterns that can help us understand our origins. The hominin lineage emerged as Earth's climate was undergoing some dramatic changes, for example. The average temperature of the planet dropped, and Africa received less rainfall. Lush tropical forests no longer covered the continent like a thick blanket. Drier woodlands and even some grasslands began to expand. Instead of steady weather patterns throughout the year, these new habitats experienced seasons of rain and drought, making supplies of food less predictable (Klein 2009).

The changing climate was likely responsible for the extinction of most early ape lineages. Of the five species of great apes alive today, four of them are found in tropical rain forests. Orangutans survive in Indonesia, while gorillas and the two species of chimpanzees—the common chimp and the bonobo—survive in Africa's forests. Their lineages remained adapted to forests, and today that dependence is helping to push them toward extinction as humans speed up the destruction of their forest homes and hunt them for food (Stanford 2012).

Hominins, on the other hand, adapted to the new ecosystems. The places in East Africa where the best hominin fossil sites are located fluctuated between grasslands and sparse woodlands between 7 and 2 million years ago before switching over to savannas (Cerling et al. 2011). Becoming bipedal may have been a key transition in the adaptation of hominins to their new environment (Lieberman 2011). As we discussed in Chapter 4, some of the oldest hominin fossils have traits that suggest they had at least some capacity to walk upright.

Scientists are exploring a number of hypotheses for why natural selection favored bipedalism in hominins. Kevin Hunt of Indiana University and his colleagues have argued that it allowed hominins to do a better job of gathering food. The more stable their bodies, the more fruit they could collect from trees. Such an origin might explain why early hominins still had broad pelvises. Such a skeleton might provide solid footing for stretching to reach fruit, although it meant that early hominins would be inefficient walkers (Hunt 1994).

As hominins became more adapted to open grasslands, other selective pressures may have driven them toward more efficient walking (**FIGURE 14.5**). Without the protection of a forest canopy, hominins would face a new challenge of intense heat on the savanna. Peter Wheeler, of Liverpool John Moores University, argues that an efficient upright stride would have helped hominins to stay cool (Wheeler 1991). By standing upright, they exposed less of their skin to the sun, and they could hold their heads up in cooler, breezier layers of air.

Teeth and Tools

Between 4 and 2 million years ago, hominins remained fairly small, and still had chimp-sized brains. Yet these hominins—collectively known as australopiths—displayed a remarkable diversity. Some were slender, with teeth that were much reduced from those of their ape ancestors. Others had a more gorilla-like build, with wide jaws and broad teeth. These differences were likely the result of the food they specialized in eating—a diverse selection that included seeds, roots, insects, fruits, and perhaps even grasses.

But teeth could get a hominin only so far. The African grasslands and woodlands swarmed with great herds of grazing mammals, for example. Lions could take down that game with their dagger-like teeth and claws and feast on the protein-rich muscle of their prey. Strong-jawed hyenas could crack open the bones to feed on the marrow inside. The small-bodied, small-toothed hominins couldn't take advantage of this abundant source of food. But that began to change when they started making stone tools.

In the last chapter, we saw how a few animals, such as chimpanzees, are adept toolmakers. Hominins likely started out with that same ancestral capacity, possibly making sticks to dig out termites or using rocks to crush nuts. But hominins evolved the mental capacity to make more powerful and versatile tools that other animals couldn't craft.

In Ethiopia, Shannon McPherron of the Max Planck Institute for Evolutionary Anthropology and his colleagues have found what may be the oldest evidence of these tools: 3.4-million-year-old bones of large mammals with distinctive cut marks (McPherron et al. 2010; **FIGURE 14.6**). Some skeptics won't be persuaded until McPherron and his colleagues find the stone tools that