A Most Improbable Story

The Evolution of the Universe, Life, and Humankind

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First edition published 2023

ISBN: 978-1-032-21854-0 (hbk)
ISBN: 978-1-032-21851-9 (pbk)
ISBN: 978-1-003-27029-4 (ebk)

12 The Genesis of Behaviorally Modern *Homo sapiens*

A Cognitively Advanced Human That Can Reflect Upon Its Existence

DOI: 10.1201/9781003270294-15

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

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> All men are by nature equal, made all of the same earth.
>
> **Plato**

> Man with all his noble qualities, with sympathy which feels for the most debased, with benevolence which extends not only to other men but to the humblest living creature, with his god-like intellect which has penetrated into the movements and constitution of the solar system—with all of these exalted powers—man still bears in his bodily frame the indelible stamp of his lowly origin.
>
> **Charles Darwin**

> A long and complex train of thought can no more be carried out without the aid of words, whether spoken or silent, than a long calculation without the use of figures or algebra.
>
> **Charles Darwin**

THE VALUE OF A GOOD TOOLSET

When humans first evolved approximately 2.4 million years ago, they made use of tools similar to those first invented by the australopithecines 200,000 years earlier [1]. These implements formed what is referred to as the Oldowan toolkit, which consisted of relatively simple hammerstones, stone cores, and stone flakes (see Figure 12.1).

Simple though they may be, these modest devices molded our lineage and our fate. Unlike many of the fierce carnivores of the African plains, our ancestors lacked powerful muscles, bone-crunching jaws, and large, sharp teeth, and so to succeed, they needed a different kind of advantage: they needed tools. The Oldowan toolkit delivered this advantage, and with these tools, our ancestors could break bones, work wood, and manipulate hides. Ultimately, these implements dramatically increased our predecessor's ability to survive and reproduce.

DOI: 10.1201/9781003270294-15

FIGURE 12.1 Tradition Oldowan choppers. (From: José-Manuel Benito Álvarez (España)—> Locutus Borg, CC BY-SA 2.5 <https://creativecommons.org/licenses/by-sa/2.5>, via Wikimedia Commons.)

About 600,000 years later, soon after *Homo erectus* evolved, a new and improved line of tools emerged. Collectively, these devices made up the Acheulean toolkit, and they include large cutting, digging, and hunting instruments such as the biface, almond-shaped hand axe (see Figure 12.2). With tools like a hand axe, *Homo erectus* could tenderize meat, cut food into small pieces, and remove cartilage and other material that is difficult to chew and digest. This food processing decreased the amount of time and energy required to eat meat and it enhanced our forbearers' net calorie and nutrient intake. With extra energy and nutrients, *Homo erectus* could power its large brain and increase its foraging range. In addition, these tools lowered the selective pressure for strong jaw muscles, large teeth, and extensive energy-intensive digestive systems, and that made it possible for the human head and neck to evolve in a way that facilitated thermoregulation, speech, and the development of still larger brains [2].

Acheulean technology proved to be remarkably stable, and the tools it produced continued to be used by various species of humans until as recently as 130,000 years ago. In total, the Acheulean toolset was employed daily for more than 1.5 million

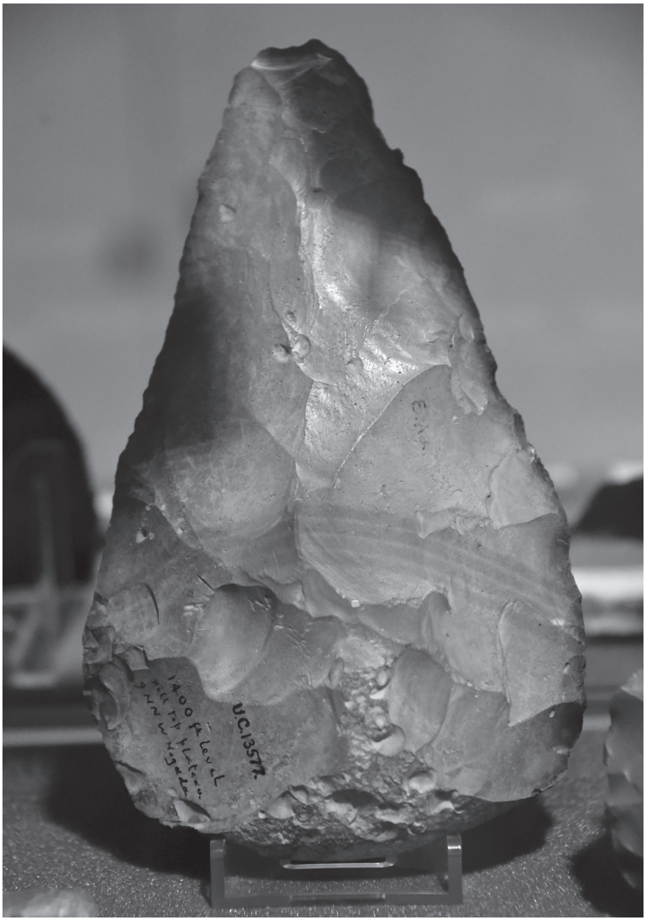

FIGURE 12.2 An Acheulean hand axe. (From: Osama Shukir Muhammed Amin FRCP (Glasg), CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons.)

years, and in the history of humankind, there has never been a similarly long-enduring technology.

FORGED BY FIRE

Another key advancement in the evolution and the expansion of humankind was the controlled use of fire. *Homo erectus* first acquired this ability about one million years ago [3], and at that time, humans likely used fire as protection from predators and as a source of heat.

By 0.5 million years ago, humans also routinely used fire to cook food [2], and the impact this development had on our evolution is hard to overestimate. Cooking decreased the likelihood of being sickened by food-borne pathogens, it greatly enhanced the caloric and nutritional value of foodstuffs, and it made many otherwise inedible plant foods suitable for consumption. These outcomes permitted our forebearers energy-intensive brains to evolve into larger and more complex structures.

By helping to break down food, cooking also decreased the need for a long digestive process. This allowed for the alteration of our jaw, teeth, digestive tract, and body trunk, and it also led to the modification of our physiology. Moreover, our new food preparation processes significantly decreased the amount of time our ancestors spent chewing. Our ape cousins dedicate up to seven hours of each day to this task [4], but with their Acheulean toolkit and culinary skills, our ancestors were able to spend less time chewing and more time acquiring additional resources.

Finally, our forebear's fire-based methods for preparing food led to the development of complicated and nuanced eating rituals. These practices influenced interpersonal bonding, group adhesion, gender dynamics, and other dimensions of our culture, and that, in turn, shaped our biological evolution [5, 6].

While fire was highly influential in shaping our past, its role in molding who and what we are continues to this day. As I write this paragraph, a car is idling in my driveway; pilot lights are flaming in my furnace, gas fireplace, and stove; and power plants are generating the electricity upon which my modern home relies. Furthermore, as I contemplate the structure of this sentence, I am also eagerly anticipating the cooked food and meal-oriented social interactions I will enjoy later this evening. All this, and much more, we owe to our ancestors' discovery of how to control fire.

THE FIRST MIGRATION OF HUMANS OUT OF AFRICA

With its large brain, modest stone tools, and the ability to harness fire, *Homo erectus* spread out across many regions of the globe. By 1.8 million years ago, these humans had left Africa [7], and within 200,000 years, they had migrated as far as the northern latitudes of northeast Asia [8]. Archaeological evidence also indicates that *Homo erectus* made its way into Europe approximately 1.2 million years ago [9].

As this species expanded its geographical range, groups splintered and drifted apart, and they began to encounter challenges unique to their location. In Europe, this process resulted in *Homo erectus* giving rise to *Homo antecessor* approximately 800,000 years ago, and in Africa, *Homo erectus* evolved into *Homo heidelbergensis,* which first appeared about 600,000 years ago. Some of the *Homo heidelbergensis* stayed in Africa, and they eventually gave rise to *Homo sapiens.* Others migrated to Eurasia where they evolved into *Homo neanderthalensis*, *Homo denisova*, and several other human species. Interestingly, there is evidence of mating between many of these clades, so some argue that these groups do not constitute separate species as defined by the BSC (see Chapter 7 for more on this). Yet, if two groups rarely mate, and if they display unique characteristics, many biologists still consider the populations to be examples of different species, even if they do occasionally produce viable, reproductively competent offspring. In this debate, it's worth once again noting the confusion that often arises because of the many ways in which biologists define a species. However, in this text, I am going to consider the groups of humans mentioned earlier to be members of different species. Having said this, it is important

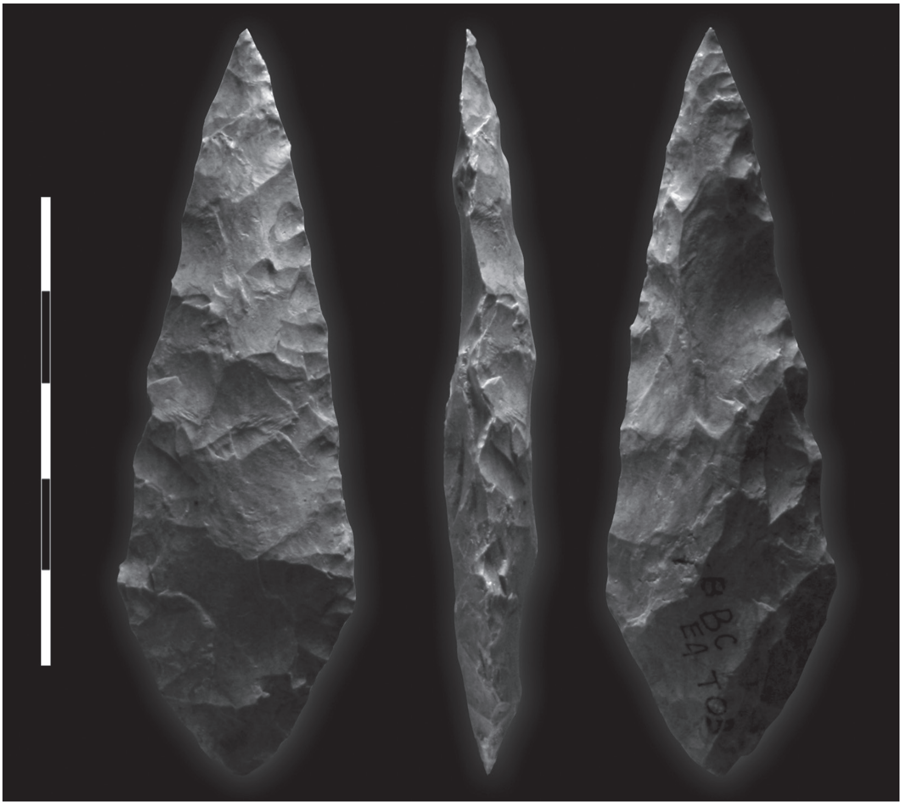

FIGURE 12.3 Middle Stone Age tools. For additional examples of this technology, see [11]. (From: Vincent Mourre/Inrap, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons.)

to keep in mind that these various human clades are so closely related that they did sometimes mate and produce offspring.

While different taxa of humans were arising in Eurasia, new groups were also appearing in Africa. One interesting faction arose about 315,000 years ago in a region known as Jebel Irhoud, which is part of the North African country of Morocco [10]. Members of this population were among the first to transition from Acheulean tools to Middle Stone Age technology (see Figure 12.3). As a result, this group of humans could produce small, pointed stone flakes, as well as stone awls that could be used to fashion hides and wooden objects. With this new toolkit, these people became less vulnerable prey, more efficient game hunters, and more significant threats to those around them.

In addition to having an unusual toolkit, the humans of Jebel Irhoud were also different because, unlike earlier members of our genus, their endocranial volume was similar to that of modern humans, and their small faces were also comparable in structure to those we possess. But, unlike us, the Jebel Irhoud population had large teeth, and they lacked a prominent chin and forehead. They also had an elongated brain case, which suggests that they had a smaller cerebellum and smaller parietal lobes than those found in modern-day humans. As a result of these differences in brain structure, the Jebel Irhoud population probably processed sensory information differently than we modern humans do, and it is likely that their communication and social skills were not as well developed as ours [12].

Despite the numerous disparities between the people of Jebel Irhoud and modern-day humans, some have argued that the Jebel Irhoud population is the oldest group of *Homo sapiens* discovered to date. Others disagree, and they believe that these individuals were not members of the *Homo sapiens* clade [13, 14]. However, regardless of how we choose to label the people of Jebel Irhoud, it is important to note that they clearly had a mixture of modern and archaic traits. Interestingly, these people were not alone in this distinction, and the evidence indicates that other human admixes were present near this time in various parts of Africa.

The fact that there were genetically different bands of *Homo sapiens* dispersed throughout Africa is not particularly surprising. The African continent is about 5,000 miles long, and at some points, it is more than 4,300 miles wide. With an area of more than 11.6 million square miles, it is the second-largest continent, and it is unusually diverse in its ecology and climate. Africa also has remarkable physical barriers, such as dense tropical forests, raging rivers, towering mountains, and hot, dry deserts. In such a place, groups that moved apart tended to remain separate, and once they were isolated, they were apt to diverge genetically, phenotypically, and culturally.

THE AFRICAN INCUBATOR

Among the physical barriers in Africa, the Sahara Desert is particularly striking, in part because it is the largest hot desert in the world. In total, the Sahara composes almost one-third of the African continent, and it has an area similar to that of China or the continental United States. Prehistoric human populations on opposite sides of this region independently adapted to environments ranging from marine coasts and rainforests to arid forests and savanna grasslands.

Had populations of *Homo sapiens* remained on opposites sides of the Sahara, they likely would have eventually speciated. However, throughout much of human history, Africa's environments have been unstable [15], and so for tens of thousands of years a region could be hot and dry, and then it could become humid and grassy for tens of thousands of years. In the case of the Sahara, a cycle of desertification and greening repeated over and over, and as a result, the desert lands were arising, fading away, and then reappearing throughout the Pleistocene. Consequently, human populations on different sides of the hot, dry Sahara could often be reunited when this area became verdant, which frequently occurred before the populations had speciated. Occasionally, during these periods of reunification, matings between previously separated groups produced "transgressive hybrids," which are individuals who exceeded either of their parents' ability to adapt to their surroundings. Once these unique individuals joined a group, their genes likely spread quickly throughout the population.

After being brought together by the greening of the Sahara, a population could be fractured once again when the area reverted to desert. As a result, the cycle of independent evolution and eventual reunification repeated, and with each round, new transgressive hybrids emerged, making the group as a whole better able to adapt. Ultimately, Africa's dynamism made it an efficient evolutionary incubator, and within this continent, individuals with new genes, gene combinations, and traits appeared.

According to those who support this view, about 50,000–80,000 years ago, Africa produced human populations that possessed most of the traits that modern humans exhibit today [16]. If this hypothesis is correct, then our species was shaped primarily within Africa over a period of hundreds of thousands of years [11, 17–19].

It is important to note that, within what I am referring to as the "African incubator," most groups that contributed to our genetic identity consisted of individuals whom most biologists would label *Homo sapiens*. However, it is likely that some of our genetic information also came from the genomes of other human species, such as *Homo naledi* and *Homo heidelbergensis*. At the time *Homo sapiens* were evolving, these species were also present on the African continent, and the pan-African amalgamation hypothesis outlined earlier leaves open the possibility that these other species also mated with *Homo sapiens* [20, 21]. Consequently, the modern human genome may be a composite that includes genetic information from several now-extinct human species of Africa.

THE AFRICAN *Homo sapiens* INVADE EURASIA

Eventually, some African *Homo sapiens* migrated to Eurasia, although exactly when this first occurred is not clear. There are fossil data that suggest *Homo sapiens* were in Greece more than 210,000 years ago, and by 180,000 years ago, they could be found in Israel [15, 22]. Evidently, when they did arrive, the *Homo sapiens* mated with the Neanderthals that were already in the region [23]. However, the evidence also suggests that these early *Homo sapiens* invaders did not fare well in their new home, and soon after arriving in Eurasia, they vanished from the region.

About 50,000–80,000 years ago, the *Homo sapiens'* situation improved, and a permanent population of *Homo sapiens* was finally established in the territory north of Africa [24]. The individuals who succeeded in constructing these long-enduring settlements were likely behaviorally modern *Homo sapiens*, and while the exact routes on which they traveled out of Africa and throughout Eurasia are debated, some have suggested that they traversed one or more of the geographical passageways displayed in Figure 12.4.

Like their ancestors, some of the modern *Homo sapiens* who entered Eurasia during this period mated with the Neanderthals that were already present, and today, the genome of people whose forebears lived outside of sub-Saharan is typically 1.5 to 2.1% Neanderthal. Individuals whose ancestors never left Africa appear to have a more limited amount of Neanderthal DNA, and it is likely that the African *Homo sapiens* acquired this Neanderthal DNA when a group of Eurasian *Homo sapiens* returned to Africa [25].

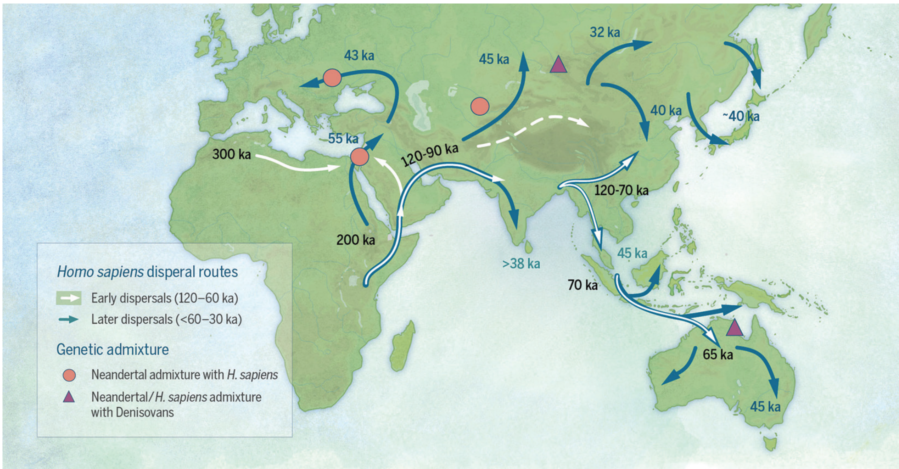

FIGURE 12.4 Geographical routes tracing the dispersion of early modern humans. Sites of genetic admixturing between *Homo sapiens* and the Neandertals and Denisovans are also depicted. (From: Katerina Douka & Michelle O'Reilly, Michael D. Petraglia, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons.)

In addition to mating with the Neanderthals, some groups of early modern *Homo sapiens* apparently intermixed with other ancient Eurasian populations such as the Denisovans. As a result, many people whose lineage can be traced to parts of Asia inherited 3 to 5% of their genetic information from this species of now-extinct humans [26, 27].

The continued presence of Neanderthal and Denisovan DNA in the genomes of modern humans suggests that this genetic information helped those who inherited it survive and reproduce in the territory outside of Africa. We know, for example, that some of the Neanderthal DNA that is in the human gene pool imparts immunological resistance to Eurasian pathogens, and other segments of this DNA affect our skin [17, 28]. The utility of having genes that impart resistance to life-threatening pathogens is obvious, but the benefits of retaining Neanderthal genes that affect the skin are not as easy to discern. However, some Neanderthal skin genes likely resulted in less skin pigmentation, and one potential benefit of lighter skin is that it can facilitate the production of vitamin D in areas with low sunlight intensity. The dark skin pigmentation of those who first left Africa absorbed much of the incoming, DNA-damaging UV light, which protected our ancestors from the destruction caused by the intense African sun, but in Eurasia, where the sunlight intensity is lower, a similar level of UV light absorption by the skin hampered vitamin D production, and in a world that lacked vitamin D enriched foods, that could have led to a potentially lethal vitamin D deficiency. As for the Denisovan genes, they likely influenced many processes, but we know that at least some were useful in low oxygen environments, such as the high-altitude Tibetan Plateau.

As was mentioned earlier, in addition to the Neanderthal and the Denisovan DNA sequences, it is likely that modern *Homo sapiens* retained DNA sequences that they acquired from other Eurasian species of humans [29]. Consequently, because of these introgressive events, the now-extinct humans of Eurasia are, in a very real sense, still with us today. As the genetic analysis of our genomes continues, we will undoubtedly learn more about how the DNA of our now extinct sister species shaped our biology and our nature.

THE AFRICAN INCUBATOR VERSUS THE EURASIAN INCUBATOR

While our species was evolving in the "African incubator," the Eurasian humans were doing the same in what could be called the "Eurasian incubator." As was true in Africa, within Eurasia, various human species mated, and there is evidence that *Homo neanderthalensis* (which were concentrated in western and central Eurasia) and *Homo denisova* (which were primarily found in the central and eastern Eurasia) produced fertile, hybrid offspring [30]. However, despite the interactions between human Eurasian species, the genetic diversity of the early Eurasian populations did not reach that found among the *Homo sapiens* in Africa [30]. Furthermore, unlike in Africa, where *Homo sapiens* eventually dominated the landscape, no one indigenous group gained control of the entirety of Eurasia.

When trying to make sense of the fate of the modern *Homo sapiens* and early Eurasian populations, it is worth pondering how each group's home continent may have played a role in their destiny. If, as I suggest, Africa was a better incubator of modern humans than was Eurasia, then during their long occupation of Africa, the modern *Homo sapiens* may have acquired adaptations that gave them a survival advantage over their Eurasian counterparts.

THE HOME-FIELD ADVANTAGE

So, what is special about Africa, and how might it have given our species an edge in the competition to survive and reproduce? Well, to start with, the human genus first emerged in Africa, and our early evolution occurred on that continent. As a result, humans were particularly well suited to life in Africa, and up until about 100,000 years ago, the vast majority of humans were concentrated in the middle latitudes of that continent (see Figure 12.5).

Within the *Homo* clade, *Homo sapiens* are a particularly young species, and as is the case with the *Homo* genus itself, we do not know where exactly our particular species emerged. As we learned earlier, the oldest putative *Homo sapiens* fossils we currently possess are from North Africa, but the oldest fully modern human fossils are the 190,000-year-old relics obtained from the East African country of Ethiopia. To further complicate matters, genetic data suggest that modern *Homo sapiens* could have first arisen in South Africa [32]. Yet, regardless of where modern *Homo sapiens* first appeared, we do know our species was shaped by matings between African populations that had been exposed to a wide range of climates, food sources, pathogens, and predators [33]. Consequently, it is likely that *Homo sapiens* developed a considerable degree of biological diversity because of the various wide-ranging environments that our African ancestors evolved within.

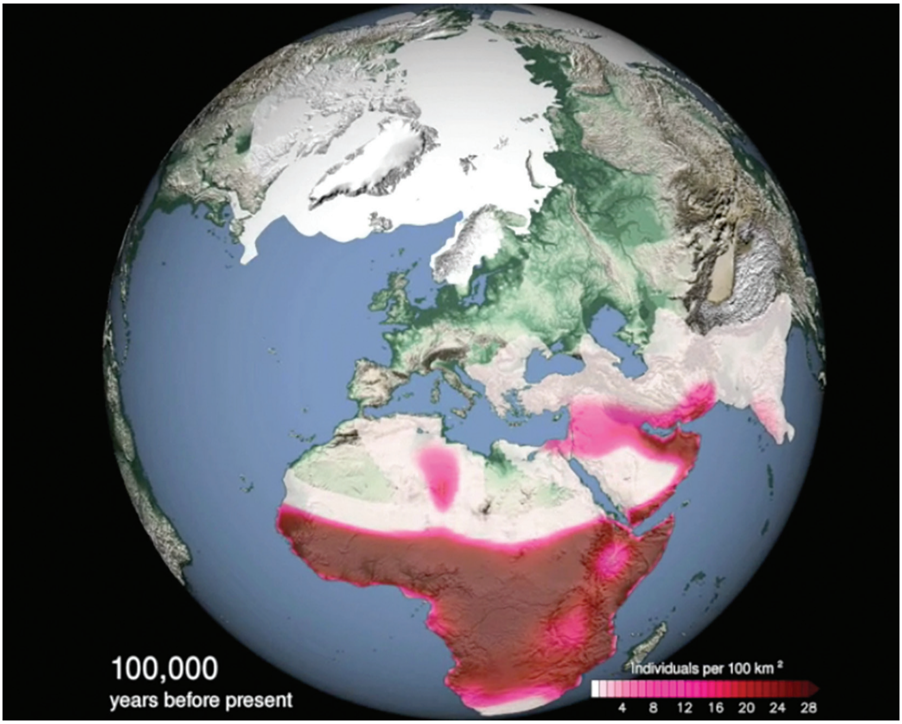

FIGURE 12.5 The geographical distribution of *Homo sapiens* 100,000 years ago [31], Human Origins Program, NMNH, Smithsonian Institution.

If the aforementioned hypothesis is correct, then the numerous and constantly changing climatic zones of Africa played an outsized role in the evolution of our kind. Interestingly, one of the reasons that Africa has so many different climes is that it is orientated along a north-south axis (see Figure 12.6). As Jared Diamond points out in his 1998 book, *Guns, Germs and Steel* [34], continents aligned in this way contain many regions that vary in latitude, and in such places, moving relatively small distances north or south often results in profound climate changes. In fact, areas on the same latitude that are separated longitudinally by four thousand miles are often more climatically like each other than landmasses on the same longitude that vary by just 1,000 miles in latitude. So, ultimately, Africa may have been particularly effective at generating modern humans because of its geographical orientation on the globe, and this suggests that the nature of the *Homo* clade in general (and the *Homo sapiens* in particular) was determined, at least in part, by the plate tectonic movements that positioned Africa and the other continents hundreds of millions of years ago (see Chapter 5).

THE PROBLEM WITH PLAYING THE AWAY GAME

Like Africa, Eurasia is enormous, and it contains many diverse environments. However, unlike humanity's original homeland, the Eurasian supercontinent has

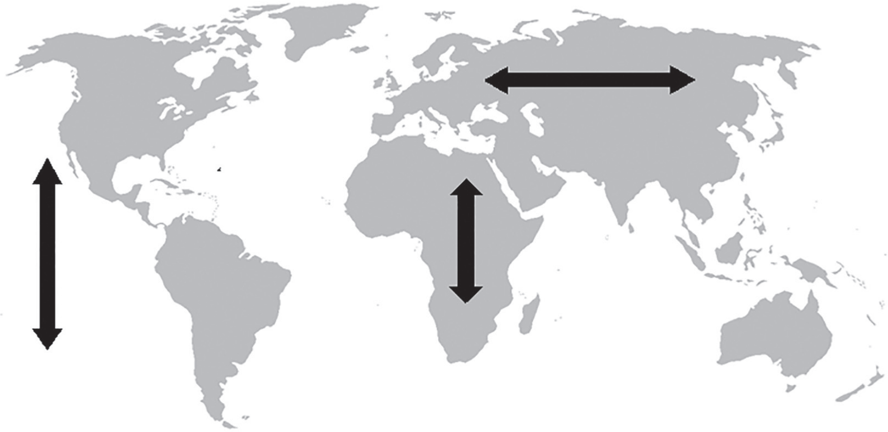

FIGURE 12.6 The orientation of the continents as described by Jared Diamond. (From: Espíritu nocturno, CC BY 4.0 <https://creativecommons.org/licenses/by/4.0>, via Wikimedia Commons.)

a horizontal orientation (see Figure 12.6). Consequently, within Eurasia, there are large tracts of land stretching from east to west that maintain similar climates and comparable environments. In addition, Eurasia also differs from Africa because it has vast regions that lie in the cold and inhospitable northern latitudes, which up until about 20,000 years ago, humans could not occupy because they lacked the technology to build warm shelters and sew clothing. Accordingly, for most of human history, large tracts of Eurasia were off-limits to humanity, and the majority of humans in this part of the world lived south of Kiev and northern Germany [34].

Ultimately, because of its orientation and location, the Eurasian continent likely produced smaller, more isolated, and genetically less diverse populations than did Africa [35]. As a result, humans migrating along the horizontal axis of the Eurasian continent would have encountered few previously established populations, and they would have been less likely to engage in intraspecies and interspecies conflicts. In addition, because they moved and settled along the horizontal axis of the Eurasian supercontinent (Figure 12.7 and https://commons.wikimedia.org/wiki/File:Köppen-Geiger_Climate_Classification_Map.png), these humans had less need for innovation, and species such as the Neanderthals could draw heavily upon their existing cultural, technological, and biological attributes as they migrated across the supercontinent. This would have been beneficial for the early Eurasian humans in the short term, but the relatively slow rate of genetic and cultural evolution that resulted may have placed the Eurasian populations at a disadvantage when they began to regularly encounter the more genetically and culturally diverse *Homo sapiens* interlopers.

Ultimately, in comparison to Africa, Eurasia may not have been as effective at accelerating the genetic and cultural evolution of its indigenous human populations. But, nevertheless, prior to the emergence of the *Homo sapiens'* behaviorally modern suite of traits, the Eurasian humans, and the African *Homo sapiens* may have been

FIGURE 12.7 The geographical distribution of *Homo neanderthalensis*. The main Neanderthal settlement sites are also indicated. (From: Berria, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons.)

close enough in their abilities that the Eurasians may have retained a numerical as well as a "home field" advantage over the early *Homo sapiens* who wandered into their territory. If true, this would explain why the first *Homo sapiens* to leave Africa around 200,000 years ago did not long endure.

While the *Homo sapiens* did not fare well in their initial attempts to leave Africa, they did much better after migrating into the Near East about 50,000–80,000 years ago [24, 36]. By then, the individuals making the trip were likely very similar to modern-day humans, and the behaviorally modern traits that they had evolved may have given this population of *Homo sapiens* the edge they needed to succeed in the new land.

THE EXTINCTION OF THE ORIGINAL EURASIANS

So, it is possible that some modern *Homo sapiens* had a competitive edge over their rivals some 50,000–80,000 years ago, but how this edge manifested is not clear. One possibility is that the modern *Homo sapiens* were better able to adapt to the climate changes that were occurring in Eurasia during this period. We know, for example, that at about this time, some of the woodlands of the Eurasian supercontinent were becoming drier and more savannah-like, and this would have been problematic for the Eurasian Neanderthals because, although they were well adapted to hunting in woodlands, they were not well suited to hunting and gathering in savannah landscapes [37]. Contrastingly, *Homo sapiens* would have benefited from this climatic alteration because they evolved in savannah landscapes.

Others have suggested that Neanderthals went extinct because their speedy metabolism, coupled with competition from modern *Homo sapiens*, caused them to starve to death. We know that the Neanderthals had a higher rate of metabolism than modern *Homo sapiens* [38], and they therefore needed more food per pound of body weight. However, because they could only use a limited range of species as a food source, and because modern *Homo sapiens* were depleting some of their options, the Neanderthals may not have had much to eat. Moreover, the Neanderthals also lacked the highly efficient social interactions and sophisticated toolset that modern *Homo sapiens* possessed [39], and therefore, it is likely that when they did compete with the modern *Homo sapiens*, they often found themselves outdone [40, 41].

The modern *Homo sapiens* may have also eliminated some members of their sister species by interbreeding with them and essentially absorbing them into their population. It is also possible that they eradicated the original Eurasians by inadvertently infecting them with lethal African pathogens [42].

Still another possible explanation for why we are still here, and our sister species are not, is that our species may have fielded a larger and better armed fighting force when they successfully began to colonize Eurasia. We know that the modern *Homo sapiens* population was more numerous than their competitors, and they were equipped with compound, projectile weapons, which the Eurasians lacked [43]. This combination of factors would have given the modern *Homo sapiens* a significant advantage if warfare between various human species did occur.

In the end, we don't know enough about the interactions between the original Eurasians and the modern *Homo sapiens* to determine exactly what happened when the two groups collided about 50,000–80,000 years ago, but we do know that, by approximately 35,000 years ago, all the original Eurasians were gone. So, after hundreds of thousands of years of sharing the planet with several other species of humans, our sister species vanished, and our species became the sole extant member of the *Homo* clade.

THE GREAT DIASPORA

At the time of our sister species' demise, our *Homo sapiens* ancestors were rapidly spreading across the globe. By about 40,000 years ago, modern *Homo sapiens* could be found throughout Eurasia and Australia, and by 12,000 years ago, they were dispersed throughout the Americas. Our ancestors even settled the remote Polynesian Islands of the South Pacific by 1,000 CE, and by the time the European explorers embarked on their global voyages, only a few small distant outposts, such as the Azores and Bermuda, remained undiscovered.

During modern *Homo sapiens'* great migrations, some populations were largely isolated from others for many thousands of years. However, within a given localized area, many groups routinely intermixed. Evidence of this phenomenon can be observed from the study of Western European genetics. About 10,000 years ago, the Western European population was composed of farmers from Iran, farmers from the Fertile Crescent, hunters and gatherers from Central and Western Europe, and hunters and gathers from Eastern Europe [36]. When these four groups first encountered each other, they were as genetically different as East Asians and Europeans are today. However, all four of these populations interbred and contributed to the modern Western European genome of the time.

Some 5,000 years after these four groups initially intermixed, the Western Europeans' genome changed significantly yet again. At this point, the Yamnaya swept into Western Europe from the Central European and Central Asian steppes. Upon arriving around the year 3000 BCE, these invading herders introduced the earlier occupants of Western Europe to exotic pathogens, domesticated horses, and the wheel. They also imposed their well-developed culture and language as well as their Iranian and Eastern European genetic heritage on those they overwhelmed [36].

Today, there is no one ethnic group that can claim that they were the original Western Europeans. Instead, it is necessary to acknowledge that Western Europeans formed from the interbreeding of a wide range of different peoples. Furthermore, given that similar intermixing occurred throughout the world, it is also true that no one group anywhere on the planet can assert that they were the "original" and "sole inhabitants" of a particular large tract of territory [44].

The fact that human populations are of a genetically mixed nature has interesting implications for those who espouse nationalistic ideologies. Chief among them is the fact that our mongrel heritage falsifies claims predicated on the idea that there are "racially pure" populations. Sadly, this reality has not stopped many from disseminating their inaccurate views about their supposedly "pure" and "unmixed" genomes.

To the dismay of many who continue to support "blood and soil" type dogmas, the integration of the human population has not abated. In fact, due to the recent construction of high-speed transportation systems that link wide-ranging social and cultural networks, it has increased. Recently, groups of non-Africans that had been isolated from each other for over 50,000 years and populations of sub-Saharan Africans that had been separated for as long as 200,000 years are now coming together and interbreeding [36]. However, all this intermingling will not result in anything particularly dramatic. This is true, in part, because even though there are genetic differences between groups, modern humans are nevertheless genetically very similar to each other, and the distinctions that do exist tend to be limited in scope.

Among the first to demonstrate that humans resemble each other genetically was Richard Lewontin. In 1972, after grouping modern humans into seven populations (West Eurasians, East Asians, South Asians, Oceanians, Australians, Native Americans, and Africans), Lewontin examined the variation in blood group proteins and various other biological markers, and he found that approximately 85% of the total variation within these marker sets could be located within any one segment of the population [45]. Based on this work, Lewontin concluded that human populations were remarkably similar, and we now know that any two individuals, regardless of where their recent ancestors came from, are about 99.4% the same at the genetic level [46]. This degree of genetic similarity is truly remarkable, and as a group, we modern *Homo sapiens* are about 10–50 times more genetically similar to each other than are individuals in most other species [46]. Indeed, some have argued that modern *Homo sapiens* are so similar that, within our species, there is not enough genetic variability to form subspecies or races [44, 47]. However, whether there are "subspecies" or "races" of humans depends on how you define these terms, and as you might expect, there are many ways in which to do so [48]. In the end, what can't be debated is that we are all genetically very much alike, and we all have a recent common ancestry. In fact, according to the Yale University statistician, Joseph Chang,

> the most recent common ancestor for the world's current population lived in the relatively recent past—perhaps within the last few thousand years. And a few thousand years before that, although we have received genetic material in markedly different proportions from the people alive at the time, the ancestors of everyone on Earth today were exactly the same [49].

Before moving on from this topic, it is important to note once again that, despite our strong similarities, there remain some genetic distinctions between human populations. For example, the degree of clustering of various genetic traits does vary between groups [50], and it is also likely that there are subtle *average* genetic differences between human populations [36]. As a result, companies like "Ancestry" and "23andMe" can analyze a series of genetic markers and attribute a specific genetic heritage to an individual, and they can also use the differences in the structure of single genes, as well as clusters of genes, to make predictions about an individual's health prospects. However, as previously isolated populations continue to intermix, groups will become even more genetically homogenous, and as that happens, our common history, as well as our shared fate, will become even more obvious.

THE "WINNING HAND" OF THE AFRICAN *Homo sapiens*

As I stated earlier, archaic *Homo sapiens* and all our sister species are gone, but we modern *Homo sapiens* are still here, and we are currently distributed across the globe. So, what made us so successful?

We know that modern *Homo sapiens* have many noteworthy traits, but our ability to use grammatical language is unique. We are also unusual in that we can generate sophisticated abstract concepts, complex logic, and deep reasoning, and we can innovate at high rates. Unfortunately, for those who are interested in these traits, grammatical language, abstract thoughts, logical thinking, and deep reasoning do not fossilize. But innovation does sometimes produce products that remain long after their creators are gone, and one ancient commodity that differentiated us from our sister species was our tools. In comparison to other humans, early modern *Homo sapiens* had better tools, more strategies for producing tools, and more varied styles of tools. In addition, with the help of our tools, early members of our species were able to generate superior weapon systems, more elaborate jewelry and body decorations, and more sophisticated representational art than any other species [36].

To some extent, the apparent disparity in innovative capabilities may have been linked to various human species' population densities. As was mentioned earlier, we know that soon after modern *Homo sapiens* arrived in Eurasia, their group expanded, and they eventually outnumbered their Neanderthal competitors by about 10:1 [35]. Due to this overwhelming demographic advantage, the modern *Homo sapiens* would have had a significant cultural and technological edge, because all else being equal, more people results in more innovation. But, in addition to large numbers, modern

Homo sapiens likely had brains that were wired differently from those of their sister species, and this too may have given our group an innovative edge.

To gain a sense of the differences in the brains of Neanderthals and modern *Homo sapiens*, archaeologists have compared their fossilized skulls. Interestingly, they found that Neanderthals and modern *Homo sapien*s had similar brain sizes, but when the two species' endocranial volumes were adjusted for body mass and the size of their visual system, they determined that the modern *Homo sapiens* had larger relative cranial volumes [51]. Moreover, recent work using techniques developed by computational neuroanatomists indicates that modern *Homo sapiens* also had larger cerebellums, and this may have given our African ancestors superior language processing skills, enhanced cognitive flexibility, and augmented memory capacities and attention spans [52].

Additional evidence suggesting the brains of modern *Homo sapiens* differed from those of Neanderthals was discovered by molecular biologists. These scientists demonstrated that Neanderthal DNA sequences in modern humans tend not to be expressed at high levels in the brain [53], which is what you would expect to see if the brains of the two species were different and there was selection against the expression of Neanderthal genes.

So, modern *Homo sapiens* brains were likely different from those of the other human species, and early modern *Homo sapiens* were apparently more innovative. But which particular neurobiological traits drove our ability to think abstractly and logically, and what specific neurological capacities helped us reason and innovate in such an extraordinary way? The answers to these questions are subject to debate, but according to many, the traits and capacities that are most responsible for our thinking are those that gave rise to our facility for grammatical language.

With grammatical language, we can more readily explore our tactical situation as well as brainstorm practical solutions to the problems we face. In addition, we can explore our feelings, revisit the past, and ponder the future through the employment of an internal monologue.

Using grammatical language, we can generate thoughts that integrate geometric and non-geometric features of our environment [54], and as a result, we can produce ideas that combine time, actors, actions, numbers, spatial dimensions, and specific attributes. We can, for instance, assemble a thought such as, "Every other Wednesday, after the guard leaves the area at about 12 p.m., two large pots of food are placed under the table in the section of the room painted red." Consequently, with our capacity to recall, integrate, and organize geometric and non-geometric features through language, we can silently produce accurate, detailed, and precise strategies and plans. In short, with grammatical language, we can think more efficiently and clearly, and therefore grammatical language is, first and foremost, an extremely powerful cognitive tool [54].

In addition to being an essential tool for cognition, spoken grammatical language is also an indispensable instrument for effective communication. Using language, our ancestors transmitted information to one another with a high degree of precision and fidelity. With this same tool, they also organized and choreographed the activities of large numbers of people, which enhanced our forebearers' ability to construct intricate social networks, complex cultures, and new innovative technologies.

So, because of evolutionary processes, our brains acquired the ability to produce grammatical language, and that, in turn, likely facilitated the evolution of our capacity to think creatively, communicate effectively, and innovate rapidly. If this is true, then our brain's facility for grammatical language may be what most distinguished us from other organisms, and this trait may be what allowed us to become the deep-thinking, civilization-producing creatures that we are.

THE GENETICS OF GRAMMATICAL LANGUAGE

Given the central importance of grammatical language, it is easy to see why there has been immense interest in locating language-enabling genes in humans, and the best studied of all language-facilitating genes is *FOXP2*.

FOXP2 encodes a transcription factor, which is a protein that regulates the expression of many other genes, and it is involved in the wiring of the basal ganglia and prefrontal cortex of the brain. In addition, *FOXP2* influences the brachial arch formation and craniofacial development. Collectively, these data indicate that *FOXP2* plays a role in forming brain structures required for language, and it is also involved in constructing the facial and neck structures necessary for spoken language [55, 56].

When *FOXP2* is mutationally inactivated, affected individuals develop profound speech and language impairments, including language processing difficulties and verbal dyspraxia (which is the inability to carry out specific and sequenced orofacial movements). In addition, individuals with mutated *FOXP2* genes exhibit glaring deficits in their ability to interpret and utilize the rules of grammar.

Remarkably, mutations in *FOXP2* do not usually alter other forms of non-verbal cognition, and even though individuals with *FOXP2* mutations often suffer from severe verbal dyspraxia, they do not typically exhibit difficulties feeding themselves, nor do they present with abnormalities in gross motor development. This information suggests that *FOXP2* primarily affects verbal cognition as well as the physiological processes required for speech production [55].

Intriguingly, the regulatory domain of *FOXP2* in modern *Homo sapiens* differs from that found in the Neanderthals, and therefore the gene itself was likely expressed differently in the two groups [57]. As a result of this genetic difference, the language abilities of modern *Homo sapiens* and Neanderthals were probably distinctive, and it is possible that modern *Homo sapiens* had superior speech and language skills as well as greater verbal cognition at least in part because of this *FOXP2* mutation. If this was the case, then FOXP2 would have granted modern *Homo sapiens* an advantage in generating language-based thoughts, and this same mutation would have allowed them to build more effective social networks. Undoubtedly, these advantages would have contributed significantly to the cultural sophistication of *Homo sapiens* as well as the rate of innovation within modern human societies.

In addition to the alterations in *FOXP2*, there were many other genetic differences that distinguished modern *Homo sapiens* from the Neanderthals [58], and since 80–95% of all human genes are expressed in the brain at some point [56], it is likely that a large number of these genetic differences affected grammatical language, reasoned thought, and rapid innovation [59, 60]. Identifying and understanding how exactly these genetic differences distinguished modern *Homo sapiens* will further enlighten our understanding of the traits that make our species particularly unusual.

THE NATURAL SELECTION OF BEHAVIORALLY MODERN HUMANS

In addition to enumerating the genes required for language and modern human behavior, many biologists would also like to determine when the genes required for these traits first appeared. Currently, we can't answer this question, but we can say that they likely emerged long before modern *Homo sapiens* permanently settled outside of Africa. The geneticist David Reich recently came to this conclusion because he and others demonstrated that there are few, if any, DNA regions (outside of the maternally inherited mitochondrial DNA and the paternally inherited Y chromosome) that all humans inherited from a recent common ancestor. Instead, they found that the segments of the genome that all currently living humans share originated in common ancestors that lived at least 320,000 years ago [36].

Reich's observation is significant because, if modern *Homo sapiens* did arise because of gene mutations that occurred right before behaviorally modern humans emerged, we would expect all modern *Homo sapiens* to have common segments of DNA (other than the mitochondria DNA and the Y chromosome), which they inherited from a recent common ancestor. But, since modern humans do not appear to have such DNA regions, and because some groups of modern humans (such as those in parts of Africa) have been separated from other groups for most of the last 200,000 years, one of the following three conditions must hold: either all of the genes that imparted the modern behavioral suite of traits arose independently and nearly simultaneously in all the non-interbreeding *Homo sapiens* populations during the last 50,000–80,000 years, or some groups of modern humans lacked the ability to generate grammatical language and complex culture, or the genes that allowed the modern behavioral suite of traits to emerge arose in an ancient population of forebearers that all modern humans have in common. Given the extreme improbability of the first condition and given that we know that all groups of modern humans employ grammatical language, it seems likely that the genes needed to produce the behaviorally modern suite of traits arose in an ancient population of common ancestors. But, if this is so, why did behaviorally modern humans only appear about 50,000–80,000 years ago?

In an attempt to answer this question, Reich suggests that, within early *Homo sapiens* populations, there were probably a large number of different genes that influenced the repertoire of characteristics exhibited by behaviorally modern humans, and he further postulates that each of these genes had a small effect on some behaviorally modern human trait [36]. So, for example, there may be versions of a gene within the population that make it more likely that an individual can generate a specific type of vocalization, and there may also be other alleles (i.e., molecular variants of a given gene) that decrease the likelihood that an individual can utter a particular type of vocalization. These genes would constitute one of many genetic regions that influence modern human behavior.

According to Reich, in the groups that lived before behaviorally modern humans first appeared, natural selection likely privileged individuals who had sets of alleles that fostered the development of some behaviorally modern traits. So, natural selection may have, for example, favored people with the alleles that made it more likely for them to produce a wide range of vocalizations, and consequently, the frequency of this specific set of alleles would have increased within human populations. Presumably, other alleles that affected other aspects of the modern behavioral repertoire would have been selected in a similar fashion.

At some point, some individuals ostensibly inherited all the alleles needed for the manifestation of the full suite of behaviorally modern traits. When that happened, the first truly behaviorally modern *Homo sapiens* emerged. Once these individuals existed, the alleles that enabled their survival advantage, i.e., the set of alleles that imparted behaviorally modern characteristics, would have been favored, and these alleles would have become more common in a population.

To support the idea that numerous alleles can undergo differential selection within a population and ultimately give rise to a particular trait, Reich points to the more than 180 DNA regions that influence height in humans. He notes that northern European populations tend to have molecular versions of the genes that increase height, while southern Europeans generally have slightly different variants of these same genes that result in shorter stature. In this case, a wide range of height alleles were very likely present in the founding populations that gave rise to the northern and southern Europeans. However, once the group fractured, there was apparently selection for alleles that increased height in northern Europe, while in southern Europe, alleles that produced a shorter stature were favored. So, Reich points out that natural selection influenced the average height of the northern and southern Europeans, but in this case, it did so not by favoring new alleles (i.e., newly mutated genes) that arose in the separate populations, but rather, by altering the frequency of existing height-affecting alleles within each distinct group. Given this, it is reasonable to assume that in a similar way, natural selection could have favored a combination of alleles that gave rise to the traits exhibited by behaviorally modern humans. So, in the ancient human populations of 320,000 years ago, all the alleles needed for modern human behavioral traits may have existed, but it wasn't until more recently that individuals with the complete set of the specific alleles needed for modern human behavior emerged.

While the aforementioned hypothesis is interesting and plausible, it still does not answer the question of why it took so long for nature to select individuals that had all the alleles needed for modern behavior. To address this issue, some suggest changes in the ecological environment occurred around 50,000–80,000 years ago, and these conditions favored the selection of the set of alleles that gave rise to behaviorally modern traits. However, if natural selection did favor a particular set of alleles, it ostensibly did so nearly simultaneously across the large swaths of the globe where humans lived at this time, and this fact makes it difficult to affirm changing ecological conditions as the primary driver in this allele selection process.

There are other potential answers to the question of why natural selection increased the frequency of the alleles that gave rise to modern human behaviors about 50,000–80,000 years ago. For example, Reich notes some sections of the human genome have still not been fully analyzed. Consequently, it is possible that there still could be unanalyzed regions of the genome that harbor behavior-inducing alleles that arose when all people still shared a recent common ancestor. However, Reich cautions that, as the genomes of various groups of humans continue to be studied, this possibility is becoming increasingly less likely.

Still another potential scenario is that modern human behavior only recently arose because *Homo sapiens* culture only recently created the conditions necessary to promote the selection of the set of alleles that gave rise to these behaviors. For example, perhaps recently emerging human cultures placed great value on grammatical language and sophisticated thought. In such environments, those that possessed these traits would be more likely to survive and reproduce. If this situation did occur, it could have led to the creation of a positive feedback loop, and as a result, the alleles that enhanced a person's ability to generate grammatical language and sophisticated thought would have quickly increased in frequency. If this is indeed what happened, then our common cultural practices influenced our genetic evolution in a very profound manner, and they induced a selection process that led to the emergence of the modern suite of human behavioral traits. Interestingly, if this scenario did occur, it apparently did so with similar kinetics across all groups of *Homo sapiens*.

THE WORLD THAT CAME AFTER THE EMERGENCE OF BEHAVIORALLY MODERN HUMANS

Regardless of exactly how and when the full suite of behaviorally modern traits arose, shortly after it did, *Homo sapiens* developed novel ideas and new ways of subsisting. Within the realm of new ideas, one of the most influential and revolutionary was that of a God. According to some scholars, the concept of a God first entered the modern human psyche about 14,000 years ago [61], and by 4,000 years ago, modern humans had developed the foundations of some of the world's largest religious traditions. Today, we have well-developed concepts of a creator God who expresses an interest in our fate and well-being, and if the theistically minded individuals among us are correct, then our species only very recently accomplished what could arguably be the most significant of all historical and evolutionary achievements, namely, the recognition that God exists.

About 10,000–12,000 years ago, soon after the idea of a God appeared, some modern humans learned that they could survive as agriculturalists. With the genesis of this new subsistence strategy, people started to transition from a nomadic hunter-gatherer lifestyle to that of a village-dwelling farmer or pastoralist, and with this change, the human population began to expand about 100 times faster than it had during much of the late Paleolithic [62]. Our species' ability to harness the power of sunlight more effectively through agriculture led to these increases, and this, in turn, fundamentally changed our fate.

Eventually, farming technology improved to the point where one farmer could produce more food than he needed, and this allowed for the development of specialists of all kinds. These specialists, and the farmers that made their existence possible, formed the first cities, which emerged about 5,500 years ago in the river valleys of the Near East, Egypt, India, and China. Within these metropolises, modern humans developed culture-altering technologies such as the wheel, writing, and metallurgy, and consequently, our kind gained new strategies for organizing each other and controlling the natural world.

If we move forward another several millennia, to about the year 1550 CE, we will observe still another monumental event, namely, the beginning of modern science. With the birth of this discipline, many humans altered how they attempted to understand the world, and soon after modern science began, additional novel ideas and technologies further revolutionized human cultures across the globe.

One particularly important byproduct of modern science was the industrial revolution, which developed around 1800. By the dawn of this era, the human population had expanded from the five million souls that existed at the start of the agricultural period to about one billion in 1804 [62, 63]. However, once humans learned how to use fossil fuels our population expanded at unprecedented rates. By tapping into the power stored in these fuels, we essentially discovered how to harvest the energy of the sunlight tied up in the remains of the ancient plants and animals, and that, in turn, made extraordinary population growth rates possible. By 1927, the number of humans had doubled to two billion, and by October 31, 2011, there were seven billion members of our kind on the planet. So, it took our species over 300,000 years to get to a population of one billion, 123 years to go from one billion to two billion, and only 12 years to go from six billion to seven billion.

As impressive and potentially worrisome as the rate of our population expansion is, the culture and technological innovations of the last two hundred are even more striking. To get a sense of this, it is worth contemplating the life of John Adams, the second president of the United States. By the dawn of the industrial age, Adams and his colleagues had come a long way from the days when our ancestors lived in trees. But, despite this reality, in 1800 the second president still had to huddle around an open fire to keep warm during the winter, and in this regard, he was behaving as our ancestors did a million years earlier. Furthermore, if we were to observe Adams and his colleagues at the beginning of the industrial revolution, we would see that the amenities most of us take for granted, such as indoor plumbing, electricity, effective medicines, and rapid transport were not available to even the most powerful individuals. In fact, in 1800, Adams and his ilk did not even have access to a bicycle, because at that point, this simple two-wheeled machine had not yet been invented.

Today, just over 200 years after Adams left the White House, the communal learning undertaken by the human population has fundamentally altered our lives. As a result, at the beginning of the 21st century, people like me move about on carbon fiber, multi-geared, GPS-guided, high-tech bicycles, and we quickly travel long distances in highly sophisticated planes, trains, and automobiles. Furthermore, once we get to our destinations, we retreat to domiciles replete with indoor plumbing, central heat, central air conditioning, portable phones, televisions, high speed, worldwide-web-connected computers, and laser-powered security systems. In the world today, if we fall ill, we arrange to see physicians who prescribe the latest battery of medicines and pain-free surgeries, and we satisfy our curiosity by making use of tools like atom smashers, DNA sequencers, and rocket ships. After two million years of incredibly slow technological advancement, human innovation suddenly increased at a breathtaking pace.

THE FUTURE OF HUMANKIND

In the year 2022, as we gaze into the future, our species is attempting to build self-driving cars, robots with artificial intelligence, and quantum computers [64, 65]. In addition, we are considering the possibility of engineering our own genomes [66], and as always, we are trying to develop new and more efficient ways to kill each other [67]. Given all this, and given the fact that our planet is constantly changing, what can we say about the prospects for humankind? Will we continue indefinitely, or will humanities' luck run out as we join the ranks of the extinct? Of course, the answer to this query is not known, but the question itself is nevertheless worth exploring. So, in the last chapter of this book, we will ponder the future of life on Earth, and we will see if we can utilize our current knowledge to gain a tentative glimpse of humankind's potential destiny.

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