Chapter 3

Opposite: Molten lava fills the sky above a volcano in Iceland. Violent natural events, now as over millions of years past, signal our planet’s dynamic nature and remind us that human evolution occurred in conjunction with ever changing environments.

SURVIVAL OF THE ADAPTABLE

When I first excavated in the rift valley, it was common knowledge that human ancestors emerged on the dry African plains,” wrote Rick Potts about his work on Olorgesailie in Kenya. “Yet scrambling up even a single gully, I couldn’t help but notice the evidence of vast change over time in the layers of that eroded landscape. Above the white silts of an ancient lake was the brown soil of a dry environment, covered by a gray ash violently spewed from a nearby volcano; then the lake returned, followed by a hard white line when the waters dried up completely. Was it the constant survival challenge of the savanna—or was change itself the more potent force behind the defining qualities of our species?”

The living world is a display of astonishing adaptations. These adaptations embrace all the structures and behaviors that have favored the survival and reproduction of organisms in the times and places in which they evolved. Powerful claws and a long, sticky tongue do a lot to assist an anteater in digging up and capturing ants. The short “flippers” of penguins are useless for flight, but along with the birds’ insulated, bullet-shaped bodies, they help them catch fish in icy Antarctic water. The idea of adaptation extends also to behavior and interactions with other species. The African honeyguide, for example, possesses a keen instinct for finding bee nests; while the honey badger, following the bird, is capable of ripping open the nests to get to the honey, which both honeyguide and badger feed upon.

Over time, a population of organisms evolves in response to the challenges and opportunities of its environment. As grasslands expanded across Africa, prehistoric antelopes evolved teeth that could efficiently chew tough blades of grass that grew on the plains. As the grazing herds expanded, flesh-eating cats became fast, effective killers, and hyenas evolved powerful jaws to crack open the nutritious marrow bones that no other carnivore could break.

Our bipedal cousins were no different. In the lineage of Paranthropus boisei the molar and premolar teeth became larger over time, and powerful jaw muscles focused the force on these teeth in a way that favored chewing tough
and abrasive foods. Considerably later, the short extremities and broad bodies of *Homo neanderthalensis* helped conserve heat and served as adaptations to the cold conditions of Europe in which this species initially evolved.

One of the basic principles of biology, therefore, is that adaptations emerge as organisms face the ongoing tests of survival in their surroundings—finding food, avoiding predators, attracting mates, warding off the cold, and locating shelter.

**ADAPTIVE CHALLENGES**

Our species, *Homo sapiens*, is recent on the evolutionary scene, having first appeared only about 200,000 years ago. Although all earlier hominins are now extinct, many of their adaptations for survival—an appetite for a varied diet, making tools to gather food, caring for each other, and using fire for heat and cooking—make up the foundation of our modern survival mechanisms and are among the defining characteristics of our species.

Life was not easy for our ancestors. Without claws or canines, the earliest hominins were physically more or less defenseless. Like other primates, they could probably toss rocks, wave sticks, and create a big fuss when threatened. They probably slept in trees at night or, at a minimum, huddled together in groups on the ground.

The hunting and scavenging efforts of later hominins, including the first to make stone tools, brought them close to animals that could injure them. They were meals for crocodiles and hyenas, as well as for big cats. Flash floods, volcanic eruptions, droughts, and other natural disasters added to their tribulations.

Early humans ultimately developed ways to cope with such dangers, but predators and scavengers always lurked. The lower jaws and limb bones of ancestors who lived between 4.4 million and 3 million years ago are often marred by the gnawing of dangerous carnivores. At the later site of Olorgesailie, where handaxes were left behind by the thousands, no early human remains came to light despite decades of searching. Then researchers were struck by the possibility that early humans at this site may have found safety in the highlands at night, when predators typically prowl near water holes. Acting on this hunch, the research team began to dig in the upper margins of the lowlands, and right away found a fossil human cranium that was 900,000 years old. The only pieces that remained were bits of the braincase and the brow ridge, which bore puncture marks from the teeth of a carnivore. This early human never made it home.

Fossil human remains evoke clues to other dangers, including illness. One example is a *Homo erectus* adult female whose skeletal remains, found at East Turkana, Kenya, were covered in a layer of abnormal bone. Researchers diagnosed a painful condition in which her bones essentially bled, caused by a disease associated with an overdose of vitamin A. How could this have happened? It turns out that the livers of carnivorous animals concentrate this vitamin at a level extremely toxic to humans, who fall victim to this terrible condition when the liver of a predator is accidentally consumed. Eating meat and even killing carnivore competitors were survival strategies of our ancestors, but in this case, a small mistake proved deadly.

Without medicine, even minor infirmities could be fatal. The robust appearance of the Kabwe cranium from Zambia belies the possibility that this *Homo heidelbergensis* individual died from a small but fatal infection. This individual is one of the oldest known to have had tooth cavities, including ten that invaded the upper teeth. A small perforation in the temporal bone of the skull leads to a larger pit on the interior and shows that either dental disease or a chronic ear infection was the cause of death.

What about fossil evidence of murder or even warfare? Wooden spears about 400,000 years old are preserved, and stone spheroids that could have been thrown date back nearly 2 million years. However, there is no evidence that multiple hominins ever died at the sites where they have been found. The earliest known death from a sharp stone point occurred in one of several Neanderthal individuals buried during thousands of years in the Shanidar Cave of northern Iraq, dated between about 45,000 and 35,000 years old. A severe wound to one of this individual’s ribs resulted from a forceful thrust of a stone tip from the left side. Before this, there is no sign of intentional injury in the fossil record. Multiple
Earth’s Changing Climate and Human Evolution

Earth’s climate has fluctuated between warm and cool over the past ten million years. The ratio of two oxygen isotopes, as measured in cores drilled from the ocean bottom, ranges from about 2.5 to 5.0 parts per million. This measure reflects both world-wide ocean temperature and the amount of glacial ice. Particularly dramatic fluctuations marked the six-million-year period of human evolution. By 6 million years ago, some hominins had controlled fire and built well-defined hearths. Most animals have an innate fear of fire and would be likely to have kept their distance from a campfire. The light from the campfire would also have helped our ancestors avoid surprise attacks. Between 800,000 and 400,000 years ago, when we see a campfire. The light from the campfire would also have helped our ancestors avoid surprise attacks. Between 800,000 and 400,000 years ago, when we see a campfire. The light from the campfire would also have helped our ancestors...
Evidence of vast swings between wet and dry, and between warm and cold, casts our own survival story in a new light.

**ERRATIC ENVIRONMENT**

Some time ago, any question concerning the environment in which humans evolved seemed entirely resolved: Early humans were adapted to the African savanna. Walking upright on two legs and making implements were critical to the survival of ancestors who ventured onto the dry, dangerous plains. As grasslands spread, hunting and eating meat proved advantageous. The control of fire staved off predators. With the expansion of early humans into Asia and Europe, the challenges of the Ice Age helped hone the capacity for social cooperation. Speaking to one another helped pass on the traditions of toolmaking. Eventually, language allowed technological innovations to catch on and creative endeavors, including art, to blossom. All the way back to the earliest bipedal predecessors, one survival skill led to another, which spurred on still newer adaptations—all against the backdrop of the arid equatorial savanna and the frigid northern landscape.

This notion of a straight line trending toward a drier, colder climate has now been replaced, however, by evidence that past climate fluctuation looked more like a rambunctious zigzag. The survival conditions of human evolution were continually revised as climate oscillated between arid and moist and between cold and warm. Scientists now speak of the environments of human evolution, with emphasis on variability. And they consider the instability of environments, not merely the expansion of grasslands or glaciers, as having shaped the evolved characteristics of human beings.

This relatively new theme in the story of human origins is still a matter of hypothesis—an overall explanation that is tested again and again as new details come to light. One of the exciting challenges in the field of paleoanthropology is to better understand how our own ancestors may have evolved adaptations to climate change to what researchers call environmental dynamics—rather than to any single setting or environmental trend.

Evidence about past climates is, naturally, an inspiration for this environmental variability hypothesis. An important record of global climate change comes from oxygen measurements in ocean microorganisms called foraminifera. Forams, as they are also known, use oxygen in their immediate surroundings to build their tiny calcareous skeletons. As the planet has cooled and warmed, the levels of different forms, or isotopes, of oxygen have changed. Because the lighter isotope more easily evaporates than the heavier one, it warmed, the levels of different forms, or isotopes, of oxygen have changed. Because the lighter isotope more easily evaporates than the heavier one, it flowed back into the ocean. Oxygen measurements of the forams obtained from the deep-ocean floor document these fluctuations in Earth’s temperature and ice volume over time.

When we look at the oxygen climate curve all the way back to 70 million years ago, we see that Earth has indeed cooled dramatically, especially over the past several million years. Important details come into focus when one examines the past ten million years. This shorter record, which includes the era of human evolution, shows that the cooling actually involved sharp fluctuations between warm and cool. The oscillations began to pick up around six million years ago, near the time the earliest human ancestors originated. The genus Homo evolved later, during a time of even greater climate fluctuation. And the immediate predecessors of our own species, Homo sapiens, evolved as climate instability mixed out with the widest oscillations.

An equally compelling climate record focuses on the moist-arid fluctuations in Africa. Cores drilled from the bottom of the Mediterranean Sea give us a long archive of black mud layers that alternate with lighter bands of silt. The two types of sediment are derived from the Nile River. The dark layers are evidence of strong monsoons that washed black mud, rich with organic material, from the huge Nile watershed into the Mediterranean, while the light bands indicate colder northern landscape.

Sediments at Olorgesailie, in Kenya, contain a wealth of information about climate change over the past 1.2 million years. White and beige sediments reflect the area’s alternation between a large lake and dry land, respectively. Brown sediments represent deposits of a river that flowed through valleys eroded into the older lake beds.
Right humerus

Homo neanderthalensis, a withered right arm (left). About 45,000 to 35,000 years old. An eagle, carried this child away. A large bird of prey, probably T. australopithecus evan’s, lived. Over the past three million years in particular, powerful climate swings experienced periods of relatively stable climate interrupted by even longer periods when strong shifts between arid and moist conditions took place. Each interval lasted from a few thousand to several hundreds of thousands of years. This long-term switching back and forth between high and low climate variability had a persistent influence on the survival and ways of life of early humans as they evolved in Africa.

Environmental records from all over the world confirm the magnitude of climate fluctuation. The longest environmental archive from any continent comes from the Loess Plateau of central China, a 400,000-square-kilometer (150,000-square-mile) region that has accumulated windblown dust over the past 2.15 million years. There, researchers have documented continuous shifting between arid and periods, when loess blew in from the northern deserts, and moist times when rich vegetation converted the loess into soil. Each of these phases lasted as long as tens of thousands of years. Although the fluctuations have occurred over many millions of years, they were especially large during the past 2.6 million years, around the same time as the glacial cycles of the Northern Hemisphere began.

Because instability in weather, food, and water inevitably posed challenges to survival, climate variability may help us make sense of the demise of many species in our own family tree. Usually it’s very difficult to pinpoint a single cause of extinction for any fossil species. Yet the habits of the large-toothed Paranthropus boisei, which lasted in Africa for a million years, or of the cold-adapted Homo neanderthalensis, which thrived in Eurasia for 200,000, were repeatedly tested as favored habitats expanded and contracted, sometimes more severely than others. Climate fluctuation also meant variation in the parasites, predators, and other dangers that challenged human ancestors where they lived. Over the past three million years in particular, powerful climate swings would have led to large fluctuations in supplies of crucial resources, contributing to occasional crashes in population size. All of these factors can influence the survival or extinction of species.

This leads to a curious finding in the study of human origins: Our closest evolutionary cousins—species that also walked upright, made tools, and had large brains—went extinct, even though these basic characteristics were at one time considered to be the hallmarks of evolutionary success in human beings. This finding brings us back to the question of adaptability. Environmental change is now understood as a prominent backdrop to the story of human origins. In the end, it may offer new insights into the origin and current status of our own species.

CLIMATE CHANGE AND EVOLUTION

The rapidly expanding data on past climate change have started to recontext our ideas about the evolution of human adaptations. What benefits did those adaptations offer as our ancestors confronted shifting conditions? The advent of upright walking, for instance, did not mean that our oldest ancestors abandoned the trees entirely. Instead, they walked across open terrain and climbed trees in more wooded areas. But later, as African environments varied dramatically between moist and dry, the ability to walk long distances would pay off well in the diverse landscapes encountered by Homo erectus. Similarly, at the dawn of stone technology, the basic toolkit—including hammerstones that could crush as forcefully as an elephant’s molar and sharp-edged flakes that could cut as finely as a carnivore’s tooth—would enable the earliest toolmakers of the genus Homo and possibly late Australopithecus to eat new kinds of food as conditions changed. Later still, as conditions continued to change, our evolving brain began to deal with richer and more complex surroundings and social interactions. Any improvement in how quickly brains could process information, call up memories, and forge new thoughts could have made the difference between survival and extinction.

One of the most impressive and unusual aspects of humans today is the way in which we alter our surroundings. Creating stone implements, controlling fire, building shelters, growing and storing food: All represent ways of altering the immediate surroundings. Each made life a bit more predictable, furthering survival in surroundings that were prone to change. The entire package proved so successful that, eventually, the sole surviving hominin—Homo sapiens—was able to spread around the globe.

Certain abilities that evolved in earlier human species proved especially beneficial in times of change. Whether or not this variability hypothesis of human evolution stands up to all the tests of scientific data down the road, the drama of environmental change is now understood as a prominent backdrop to the story of our origins. In the end, it may offer new insights into the origin and current status of our own species.

FAQ:

How does evolution occur?

C
enetic variation is fundamental to evolution. A popula-
tion’s gene pool undergoes slight changes every genera-
tion because of mutation and the recombining of parents’ DNA
in their offspring.

To survive, living things adapt to their surroundings. Natural
selection provides an important mechanism for change in a
population’s gene pool over time. A genetic variation occasionally
gives a member of a species an edge. That individual passes the
beneficial gene on to his or her descendants. More individuals with
the new trait survive and pass it on to their descendants. If many
beneficial traits arise over time, a new species—better equipped
to meet the challenges of its environment—can evolve.