VINTAGE

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Lewis Dartnell is an astrobiology researcher and professor at the University of Westminster. He has won several awards for his science writing, and contributes to the *Guardian, The Times* and *New Scientist*. He has also written for television and appeared on BBC Horizon, Sky News, and Wonders of the Universe, as well as National Geographic and History channels. A tireless populariser of science, his previous books include the bestselling *The Knowledge: How to Rebuild Our World from Scratch*.

ALSO BY LEWIS DARTNELL

Life in the Universe: A Beginner's Guide

My Tourist's Guide to the Solar System and Beyond

The Knowledge: How to Rebuild Our World from Scratch

Origins

HOW THE EARTH MADE US

LEWIS DARTNELL

THE BODLEY HEAD
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Introduction

Why is the world the way it is?

I don't mean this in a musing philosophical way – why are we all here? – but in a deep scientific sense: what are the reasons behind the major features of the world, the physical landscape of continents and oceans, mountains and deserts? And how have the terrains and activities of our planet, and beyond that our cosmic environment, affected the emergence and development of our species and the history of our societies and civilisations? In what ways has Earth itself been a leading protagonist in shaping the human story – a character with distinctive facial features, a variable mood, and prone to occasional fractious outbursts?

I want to explore how the Earth made us. Of course, each of us is literally made of the Earth, as is all life on the planet. The water in your body once flowed down the Nile, fell as monsoon rain onto India, and swirled around the Pacific. The carbon in the organic molecules of your cells was mined from the atmosphere by the plants that we eat. The salt in your sweat and tears, the calcium of your bones, and the iron in your blood all eroded out of the rocks of Earth's crust; and the sulphur of the protein molecules in your hair and muscles was spewed out by volcanoes.[1] The Earth has also provided us with the raw materials we've extracted, refined and assembled into our tools and technologies, from the roughly fashioned hand axes of the early Stone Age to today's computers and smartphones.

It was our planet's active geological forces that drove our evolution in East Africa as a uniquely intelligent, communicative and resourceful kind of ape,[fn1] while a fluctuating planetary climate enabled us to migrate around the world to become the most widely spread animal species on Earth. Other grand-scale planetary processes and events created the different landscapes and climate regions that have directed the emergence and development of civilisations throughout history. These planetary influences on the human story range from the seemingly trivial to the deeply profound. We'll see how a sustained cooling and drying in Earth's climate is the reason why most of us eat a slice of toast or a bowl of cereal for breakfast; how continental collision created the Mediterranean as a bubbling cauldron of diverse cultures; and how the contrasting climate bands within Eurasia fostered fundamentally contrasting ways of life that shaped the history of peoples across the continent for millennia.

We have become greatly concerned about humanity's impact on the natural environment. Over time our population has exploded, consuming ever more material resources and marshalling energy sources with greater and greater proficiency. *Homo sapiens* has now come to replace Nature as the dominant environmental force on Earth. Our building of cities and roads, damming of rivers, and industrial and mining activity are having a profound and lasting effect, remoulding the landscape, changing the global climate and causing widespread extinctions. Scientists have proposed that a new geological epoch should be named to recognise this dominance of our influence over natural processes on the planet – the Anthropocene, the 'recent age of humanity'.[2] But as a species we are still inextricably linked to our planet, and the Earth's history is imprinted in our make-up, just as much as our activities have left their distinct marks on the natural world. To truly understand our own story we must examine the biography of the Earth itself – its landscape features and underlying fabric, atmospheric circulation and climate regions, plate tectonics and ancient episodes of climate change. In this book we'll explore what our environment has done to *us*.

In my previous book, The *Knowledge*,[3] I set out to solve a thought experiment: how we might reboot civilisation from scratch as quickly as possible after some kind of hypothetical apocalypse. I used the notion of the loss of all that we take for granted in our everyday lives to explore how civilisation works behind the scenes. The book was essentially an investigation of the key scientific discoveries and technological innovations that enabled us to build the modern world. What I want to do this time is broaden the perspective, to discuss not just the human ingenuity that got us to where we are today, but to follow the threads of explanation back even further. The roots of our modern world stretch far back in time, and if we trace them deeper and deeper across the changing face of the Earth, we uncover lines of causation that often take us all the way back to the birth of our planet.

Anyone who's ever chatted with children will know what I mean here. For an inquisitive six-year-old asking about how something works or why something is the way it is, your immediate answer is never satisfactory. It opens up further mysteries. A simple initial question invariably leads to a whole series of 'why?', 'but why?', 'why is that?' With an unquenchable curiosity, the child tries to get to grips with the underlying nature of the world it finds itself in. I want to explore our history in the same way, drilling downwards through more and more fundamental reasons and investigate how seemingly unrelated facets of the world in fact share a deep link.

History is chaotic, messy, random – a few years of poor rainfall lead to famine and social unrest; a volcano erupts and annihilates nearby towns; a general makes a bad decision among the sweaty clamour and gore of the battlefield and an empire is destroyed. But beyond the particular contingencies of history, if you look at our world on a broad enough scale, both in terms of time and space, reliable trends and dependable constants can be discerned, and the ultimate causes behind them explained. Of course, our planet's make-up has not preordained everything, but profound overarching themes can nonetheless be distinguished.

Our survey will reach over a staggering span of time. The entirety of human history has played out on an essentially static map – within but a single frame of the Earth's movie. But the world hasn't always looked like this, and although continents and oceans shift over geologically slow timescales the past faces of the Earth have greatly influenced our story. We'll look at the changing nature of the Earth and the development of life on our planet over the past few *billion* years; the evolution of humans from our ape ancestors over the last five *million* years; the increase in human capabilities and dispersal around the world over the past *hundred thousand* years; the progression of civilisation over the last *ten thousand* years; the most recent trends of commercialisation, industrialisation and globalisation of the last *millennium*; and finally how we have come to understand this wondrous origin story over the last *century*.

In the process we'll travel to the ends of history – and beyond. Historians decipher and interpret humanity's written accounts to tell the story of our earliest civilisations. Archaeologists brushing the dust off ancient artefacts and ruins can tell us about our earlier prehistory and lives as hunter-gatherers. Palaeontologists have pieced together our evolution as a species. And to peer even further back through time we will turn to revelations from other fields of science: we will be browsing the records preserved in the layers of rocks that make up the very fabric of our planet; we will be reading the ancient inscriptions of the genetic code stored in the DNA library inside each of our cells; and we will be peeping through telescopes to survey the cosmic forces that shaped our world. The narrative threads of history and science will be intertwined throughout the book, making up the warp and weft of its fabric.

Every culture has developed its own origin story – from the Australian Aborigines' Dreamtime to the Zulus' creation myth. But modern science has built up an increasingly complete and fascinating account of how the world around us came to be, and how we took our place within it. Rather than relying solely on our imagination, we can now elucidate the chronicle of creation by using these tools of investigation. This, then, is the ultimate origin story: the tale of the whole of humanity and also that of the planet we live on.

We'll explore why the Earth has been experiencing a prolonged cooling and drying trend over the past few tens of millions of years, and how this created the plant species we came to cultivate and the herbivorous mammals we domesticated. We'll investigate how the last ice age enabled us to disperse across the globe, and why it is that humanity only came to settle down and develop agriculture in the current interglacial period. We'll look at how we have learned to extract and exploit a huge diversity of metals from the crust of the planet that have driven a succession of revolutions in tool-making and technology throughout history; and how the Earth gave us the fossil energy sources that have powered our world since the Industrial Revolution. We'll discuss the Age of Exploration in the context of the fundamental circulation systems of the Earth's atmosphere and oceans, and how seafarers came to understand wind patterns and ocean currents step by step to build transcontinental trade routes and maritime empires. We'll explore how the Earth's history has created the geostrategic concerns of today, and continues to influence modern politics – how the political map of the south-eastern US continues to be shaped by sediments from an ancient sea that existed 75 million years ago, and how voting patterns in Britain reflect the location of geological deposits dating to the Carboniferous Period 320 million years ago. It is through knowing our past that we can understand the present, and prepare ourselves to face the future.

We'll begin our ultimate origin story with the most profound question of all: what planetary processes drove the evolution of humanity?

Chapter 1

The Making of Us

We are all apes.

The human branch of the evolutionary tree, called the hominins, is part of the wider animal group of the primates.[fn1] Our closest living relatives are the chimpanzees. Genetics suggest that our divergence from the chimps was a long and drawn-out process, beginning as early as 13 million years ago, with interbreeding continuing until perhaps 7 million years ago.[1] But eventually our evolutionary histories did separate, with one side giving rise to today's common and bonobo chimpanzee, the other branching into the different hominin species, with our own kind, *Homo sapiens*, forming just one twig. If we look at our development in this way, humans didn't evolve *from* apes – we *are* still apes, in the same way that we're still mammals.

All the major transitions in the evolution of hominins took place in East Africa. This region of the world lies within the rainforest belt around the equator of the planet, on a level with the Congo, the Amazon and the tropical islands of the East Indies. By rights, therefore, East Africa ought to be densely forested too, but is instead characterised by mainly dry, savannah grasslands. While our primate ancestors were tree-dwellers, surviving on fruit and leaves, something drastic happened in this region of the world, our birthplace, to transform the habitat from lush forest to arid savannah, and in turn drive our own evolutionary trajectory from tree-swinging primates to bipedal hominins hunting across the golden grasslands.

What are the planetary causes that transformed this particular region to create an environment in which smart, adaptable animals could evolve? And as we are only one of a number of similar intelligent, tool-using hominin species to have evolved in Africa, what were the ultimate reasons why *Homo sapiens* prevailed to inherit the Earth as the sole survivor of our evolutionary branch?

GLOBAL COOLING

Our planet is a restlessly active place, constantly changing its face. Fast-forwarding through deep time you'd see the continents gliding between myriad different configurations, frequently colliding and welding together only to be ripped apart again, with vast oceans opening and then shrinking and disappearing. Great chains of volcanoes pop and fizzle, the ground shivers with earthquakes, and towering mountain ranges crumple out of the ground before being ground away back to dust. The engine powering all this fervent activity is plate tectonics, and it is the ultimate cause behind our evolution.

The outer skin of the Earth, the crust, is like a brittle eggshell encasing the hotter, gooier, mantle beneath. The crustal shell is cracked, fragmented into many separate plates that rove across the face of the Earth. The continents are made up of a thicker crust of less dense rocks, while the oceanic crust is thinner but heavier and so doesn't ride as high as the continental crust. Most of the tectonic plates are made up of both continental and oceanic crust, and these rafts are constantly jostling for position with each other as they bob on top of the hot churning mantle and ride the whims of its currents.

Where two plates butt into one another, along what is known as a convergent plate boundary, something has got to give. The leading edge of one of the two plates is shunted beneath the other and is dragged down into the rock-melting heat of the mantle, triggering frequent earthquakes and feeding an arc of volcanoes. Because the rocks of the continental crust are less dense and so more buoyant, it is almost invariably the oceanic crust portion that sinks beneath the other in a plate collision. This subduction process continues until the intervening ocean has been swallowed, and the two chunks of continental crust become welded together, a great crumpled chain of mountains marking the impact line.

Divergent, or constructive, boundaries are the places where two plates are being pulled apart from each other. Hot mantle from the depths rises up into this rent, like blood welling into a gash in your arm, and solidifies to form new rocky crust. Although a new spreading rift can open up in the middle of a continent, ripping it in two, this fresh crust is dense and low-lying and so becomes flooded over with water. Constructive boundaries form new oceanic crust – the Mid-Atlantic Ridge is one prominent example of such a seafloor spreading rift.[2]

Plate tectonics is an overarching theme of the Earth we'll return to throughout the book, but for now we'll focus on how the climate change it drove over recent geological history produced the conditions for our own creation.

The past 50 million years or so have been characterised by a chilling of the global climate. This process is called the Cenozoic cooling, and it culminated 2.6 million years ago in the current period of pulsing ice ages that we'll look at in detail in the next chapter. This long-term global cooling trend has been largely driven by the continental collision of India into Eurasia and the raising of the Himalayas. The subsequent erosion of this towering ridge of rocks has scrubbed a lot of carbon dioxide out of the atmosphere, resulting in a reduction of the greenhouse effect that was previously insulating the planet (see Chapter 2), and leading to declining temperatures. In turn, the generally cooler conditions drove less evaporation from the oceans to create a less rainy, drier world.

Although this tectonic process happened some 5,000 kilometres away across the Indian Ocean, it also had a direct regional effect within the theatre of our evolution. The Himalayas and Tibetan Plateau have created a very powerful monsoon system over India and South-East Asia. But this huge atmospheric sucking effect over the Indian Ocean also drew moisture away from East Africa, reducing the rainfall it experienced. Other global tectonic events are thought to have contributed to the aridification of East Africa. Around 3–4 million years ago Australia and New Guinea drifted north, closing an ocean channel known as the Indonesian Seaway as they did so. This blockage constricted the westward flow of warm South Pacific waters, and instead colder waters from the North Pacific flowed through to the central Indian Ocean. A cooler Indian Ocean reduced evaporation which in turn meant less rainfall for East Africa.[3] But most significantly, another huge tectonic upheaval was happening in Africa itself that was to prove instrumental in the making of us.

A HOTBED OF EVOLUTION

About 30 million years ago a plume of hot mantle rose up beneath north-eastern Africa. The land mass was forced to swell upwards by about a kilometre like a huge zit.[4] The skin of continental crust over this swollen dome stretched and thinned until eventually it began to rip open right across the middle in a series of rifts. The East African Rift tore along a roughly north–south line, forming an eastern branch through what is now Ethiopia, Kenya, Tanzania and Malawi, and a western branch that cuts through Congo and then continues along its border with Tanzania.

This Earth-ripping process was more intense towards the north, tearing right through the crust to allow magma to seep through the long wound and create a new crust of basalt rock. Water then flooded into this deep rift to create the Red Sea; another rift became the Gulf of Aden. The seafloor spreading rifts tore off a chunk from the Horn of Africa to form a new tectonic plate, the Arabian. The Y-shaped meeting of the African Rift, Red Sea and Gulf of Aden is known as a triple junction and right at the centre of this intersection is a low-lying triangle of land called the Afar region, stretching across north-east Ethiopia, Djibouti and Eritrea.[5] We'll return to this important region later.

The East African Rift runs for thousands of kilometres from Ethiopia to Mozambique. As the swelling from the magma plume bulging beneath it continues, the Rift is still being pulled apart. This 'extensional tectonic' process is causing whole slabs of rock to fracture along faults and break off, with the flanks being pushed up as steep escarpments and the blocks in between subsiding to form the valley floor. Between about 5.5 and 3.7 million years ago this process created the current landscape of the Rift: a wide, deep valley half a mile above sea level and lined on both sides with mountainous ridges.[6]

One major effect of the swelling of this crustal bulge and the high ridges of the Rift was to block rainfall over much of East Africa. Moist air blowing over from the Indian Ocean is forced upwards to higher altitudes where it cools and condenses, falling as rain near the coast. This creates drier conditions further inland – a phenomenon known as a rain-shadow.[7] At the same time, the moist air from the central African rainforests is also blocked from moving eastwards by the highlands of the Rift.[8]

The upshot of all these tectonic processes – the creation of the Himalayas, the closing of the Indonesian Seaway, and in particular the uplift of the high ridges of the African Rift – was to dry out East Africa. And the formation of the Rift changed not only the climate but also the landscape, in the process transforming the ecosystems of the area. East Africa was remoulded from a uniform, flat area smothered in tropical forest, to a rugged, mountainous region with plateaus and deep valleys, its vegetation ranging from cloud forest to savannah to desert scrub.[9]

Although the great rift started to form around 30 million years ago, much of the uplift and aridification happened over the past 3–4 million years.[10] Over this time, the same period that saw our evolution, the scenery of East Africa shifted from the set of *Tarzan* to that of *The Lion King*.[11] It was this long-term drying out of East Africa, reducing and fragmenting the forest habitat and replacing it with savannah, that was one of the major factors that drove the divergence of hominins from tree-dwelling apes. The spread of dry grasslands also supported a proliferation of large herbivorous mammals, ungulate species like antelope and zebra that humans would come to hunt.

But it wasn't the only factor. Through its tectonic formation the Rift Valley became a very complex environment, with a variety of different locales in close proximity: woods and grasslands, ridges, steep escarpments, hills, plateaus and plains, valleys, and deep freshwater lakes on the floor of the Rift.[12] This has been described as a mosaic environment, offering hominins a diversity of food sources, resources and opportunities.[13]

The widening of the Rift and the upwelling of magma was accompanied by strings of violent volcanoes spewing pumice and ash across the whole region. The East African Rift is dotted with volcanoes along its length, many of which formed in just the last few million years. Most of these lie within the Rift Valley itself, but some of the largest and oldest are growing on the edges, including Mt Kenya, Mt Elgon, and Mt Kilimanjaro, the tallest mountain in Africa.

The frequent volcanic eruptions spilled lava flows that solidified into rocky ridges cutting across the landscape. These could be traversed by nimble-footed hominins, and along with the steep scarp walls within the Rift may have provided effective natural obstacles and barriers for the animals they hunted. Early hunters were better able to predict and control the movements of their prey, constraining escape routes and directing them into a trap for the kill. These same features may also have offered vulnerable early humans a degree of protection and security from their own predators that prowled the landscape.[14] It seems that this rough and varied terrain provided hominins with the ideal environment in which to thrive. Early humans, who, like us, were relatively feeble and did not have the speed of a cheetah or the strength of a lion, learned to work together and take advantage of the lie of the land, with all its tectonic and volcanic complexity, to help them hunt.

It is active tectonics and volcanism that have created and then sustained these features of a varied and dynamic landscape over the course of our evolution. In fact, because the African Rift is such a tectonically active region, the landscape has changed greatly since the times of earliest human habitation. As the Rift has continued to widen, the areas once populated by hominins on the valley floor have now become uplifted onto the flanks of the Rift; today it is here that we find hominin fossils and archaeological evidence, completely removed from their original settings. And it is this great rift, the most substantial and long-lived region with extensional tectonics in the world today, that is believed to have been crucial to our evolution.

FROM TREES TO TOOLS

The first indisputable hominin for which we have discovered good fossil remains is *Ardipithecus ramidus*, which lived around 4.4 million years ago in forest lining the Awash river valley in Ethiopia. This species was roughly the same size as modern chimpanzees, with an equivalent-sized brain, and teeth that suggest they had an omnivorous diet. The fossilised skeletons indicate they still lived in trees and had only developed a primitive bipedality – the ability to walk upright on two feet. About 4 million years ago, the first members of the genus *Australopithecus* – the 'southern ape' – shared several traits with modern humans, such as a slender and gracile body-form (but still with more primitive skull shapes), and they were competent at walking bipedally. *Australopithecus afarensis*, for example, is well known from surviving fossils. One of these is the remarkably complete skeleton of a female who lived 3.2 million years ago in the Awash river valley, which came to be known as Lucy.[fn2]

Lucy would have stood at only about 1.1 metres, but had a spine, pelvis and leg bones very similar to those of modern humans. So while Lucy, and other members of *A. afarensis*,[fn3] still had a small, chimpanzee-sized brain, their skeleton clearly indicates a lifestyle of long-distance bipedal walking. Indeed, a bed of volcanic ash in Laetoli, Tanzania, has preserved three sets of footprints from 3.7 million years ago. These were probably created by members of *A. afarensis* and look remarkably like those you might leave in the sand during a stroll along the beach.

In human evolution, the development of bipedalism clearly came a long way before significant increases in brain size – we walked the walk before we could talk the talk. These *Australopithecus* fossils, together with those of the earlier *Ardipithecus* species, also show that bipedality didn't evolve as an adaptation to walking in open, grassy savannah environments as had been thought previously, but first emerged with hominins still living closely among trees in wooded areas.[15] But bipedalism certainly became an increasingly useful adaptation as the forests shrank and became more fragmented. Our early hominin ancestors were able to move between islands of woods, and then venture out into the grasslands. Bipedalism allowed them to see over the tall grass, and minimised the area of their bodies exposed to the hot sun, helping them to keep cool in the savannah heat. And the opposable thumbs that became so useful for holding and manipulating tools are also an evolutionary inheritance from our forest-dwelling primate ancestors. The hand crafted by evolution to grasp a tree branch pre-adapted us for holding the shaft of a club, an axe, a pen, and ultimately the control stick of a jet plane.

By around 2 million years ago the hominin species of the *Australopithecus* genus had all fallen extinct and our own genus, *Homo*, had emerged from them. *Homo habilis* ('handy man') was the first, with a gracile body-form similar to the earlier australopithecines and a brain only slightly larger.[16] A dramatic increase in the size of the body and brain, as well as a major shift in lifestyle, however, came with *Homo erectus*, which appeared around 2 million years ago in East Africa. Below the skull, the skeleton of *H. erectus* is very similar to that of anatomically modern humans, including adaptations for long-distance running and a shoulder design that would have allowed the throwing of projectiles. They are also thought to have exhibited other traits shared with us, like long childhoods of slower development and advanced social behaviour.

H. erectus was probably also the first hominin to live as a hunter-gatherer and to control fire – not just for warmth but possibly also for cooking their food.[17] They may even have used rafts to travel over large bodies of water.[18] By 1.8 million years ago *H. erectus* had spread across Africa and then became the first hominin to leave the continent and disperse through Eurasia, probably in several independent waves of migration.[19] This species persisted for almost 2 million years. By contrast, anatomically modern humans have only been around for a tenth of that time – and at the moment we'd be lucky to survive the next 10,000 years, let alone 2 million.

H. erectus gave rise to *Homo heidelbergensis* around 800,000 years ago, which by 250,000 years ago had developed into *Homo neanderthalensis* (the Neanderthals) in Europe and the Denisovan hominin in Asia. The first anatomically modern human, *Homo* *sapiens*, emerged in East Africa between 300,000 and 200,000 years ago.

Over the course of human evolution, hominins became increasingly bipedal, and then more efficient long-distance runners,[20] with changes to the skeleton including an S-shaped spine, a bowl-like pelvis and longer legs to support this upright posture and mode of locomotion. Body hair became reduced, except on the scalp. The shape of the head also transformed, producing a smaller snout with a more pronounced chin, and a more bowl-shaped brain case.[21] Indeed, the major difference between the earlier *Australopithecus* genus and our *Homo* lineage was this increase in brain size. Throughout their 2 million years of evolution the australopithecines' brain size was strikingly constant at around 450 cm^3, roughly equivalent to that of a modern chimpanzee. But *H. habilis* had a brain a third larger, at about 600 cm^3, and brain size doubled again from *H. habilis* through *H. erectus* to *H. heidelbergensis*. By 600,000 years ago, *H. heidelbergensis* had a brain roughly the same size as that of modern humans, and three times larger than that of australopithecines.[22]

As well as increasing brain size, another defining feature of the hominins was how we applied our intelligence to tool-making. The earliest widespread stone tools – known as Oldowan technology – date back to about 2.6 million years ago, and were used by the later *Australopithecus* species as well as *H. habilis* and *H. erectus*. Rounded cobbles from a river were used for cracking open bones or nuts against another, flat, anvil stone. Sharpened edges were created by chipping off flakes, and this shaped stone was then used for cutting and scraping meat from a kill, or for wood-working.[fn4]

A revolution in Stone Age technology came when *H. erectus* inherited Oldowan tools and refined them into the Acheulean industry 1.7 million years ago. Acheulean tools are more carefully worked by knocking off smaller and smaller flakes to create more symmetrical and thinner, pear-shaped hand-axes. They have represented the dominant technology for the vast majority of human history. A later transformation produced the Mousterian technology, used by Neanderthals and anatomically modern humans through the Ice Age. Here, the core stone was carefully prepared and trimmed by knapping around the edge, before a final, large flake was skilfully knocked off. It was the removed flake rather than the shaped core stone that was the goal: a thin, pointed shard was perfect as a knife or could be used as a spear point or arrowhead.[23]

These stone tools, as well as wooden spear shafts, enabled hominins to become fearsomely effective hunters without needing to develop large teeth or claws on their own bodies like other predators. We exploited sticks and stones as artificial teeth and claws to hunt for food or to defend ourselves, all whilst being able to keep a safe distance from prey and predators to minimise the risk of injury.

These developments in body-form and lifestyle enhanced each other. More efficient running and sophisticated cognitive abilities, coupled with tool use and control of fire, enabled more effective hunting and a diet with an ever greater proportion of meat for powering a larger brain. This in turn enabled us to develop more complex social interaction and cooperation, cultural learning and problem solving, and perhaps most significantly, language.[24]

THE CLIMATE PENDULUM

Many of these landmark transitions in our evolution are preserved within the Afar region – the triangular depression that as we saw sits right at the intersection of the tectonic triple junction – at the northern, and oldest, end of the Rift. The first hominin fossils, those of *Ardipithecus ramidus*, were discovered in the Awash river valley that runs north-east from the Ethiopian plateau towards Djibouti, flowing right through the middle of the Afar triangle.

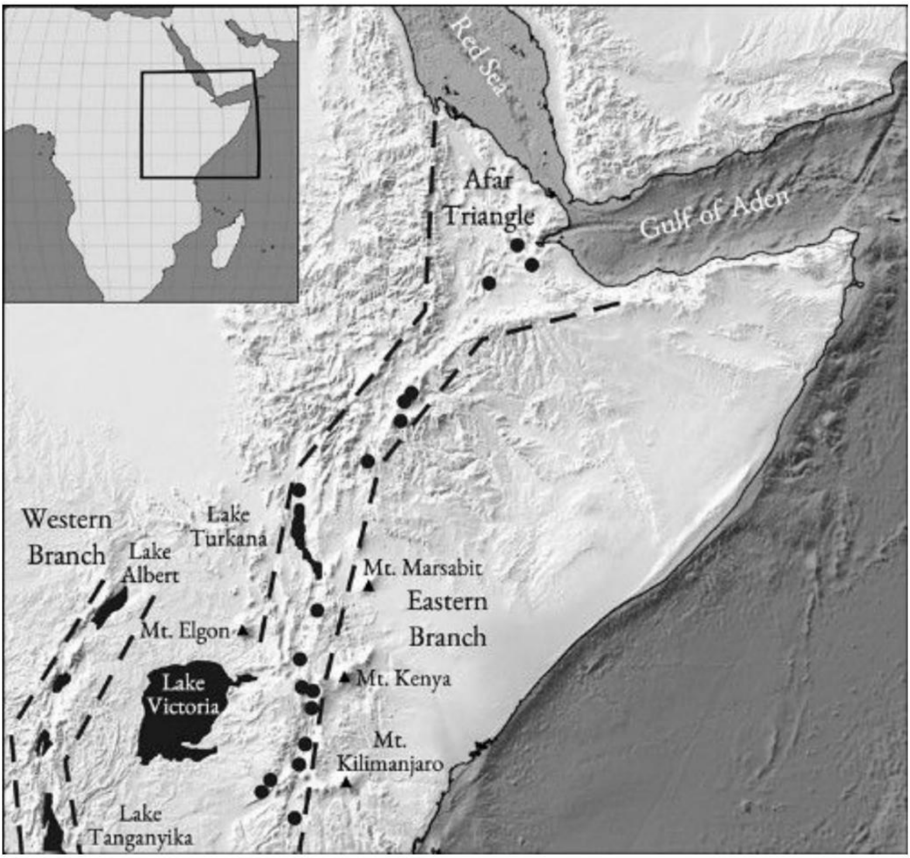
This same river valley preserved the 3.2 million-year-old remains of Lucy – indeed, her entire species, *Australopithecus afarensis*, was named for this region. And the oldest known Oldowan tools were found in Gona, Ethiopia, which also lies within the Afar triangle. But the whole length of the East African Rift Valley has been a hotbed of hominin evolution.

The drying climate and the rift system with its mosaic of varied features, including volcanic ridges and fault scarps, were clearly instrumental in providing the environmental conditions to drive our evolution. But while this complex, tectonic landscape may have provided opportunities for roaming hominins, it doesn't explain sufficiently how such incredible versatility and intelligence emerged in the first place. The answer is thought to come down to a particular quirk of the extensional tectonics of the great Rift Valley, and how it interacts with fluctuations in the climate.

As we have seen, the world has been getting generally cooler and drier for the past 50 million years or so, and the tectonic uplift and formation of the Rift Valley has meant that East Africa in particular dried out and lost its former forests. But within this global cooling and drying trend, the climate became very unstable and swung back and forth dramatically. As we will discover in more detail in the next chapter, around 2.6 million years ago the Earth slid into the current epoch of the ice ages, with its alternating glacial and interglacial phases driven by rhythmical shifts in Earth's orbit and tilt known as the Milankovitch cycles. East Africa was too far from the poles to encounter the advancing ice sheets themselves, but this doesn't mean it wasn't greatly affected by these cosmic cycles. In particular, the periodic stretching of Earth's orbit around the Sun into a more elongated egg shape – known as the eccentricity cycle – has produced periods of highly variable climate in East Africa. During each of these phases of extreme variability, the climate oscillates back and forth between very arid and wetter conditions, with the faster beat of the precession cycle of Earth's tilted axis, which we'll come back to.[25]

Still, these cosmic periodicities and the swings in climate they drive operate over thousands and thousands of years. If we want to understand human evolution, the mystery is that processes which have had the biggest influence on East Africa – such as the overall drying effect from tectonic uplift and rifting within the region, or climate rhythms like the precession of Earth's axis – operate on an exceedingly slow timescale compared to the lifespan of an animal. Yet intelligence, and the extremely versatile behaviour it allows, is an adaptation similar to the use of a multi-tool Swiss army knife, helping an individual cope with diverse challenges as the environment varies significantly within its lifetime. Environmental changes over a much longer timescale can be met by evolution adapting the body or physiology of a species over the generations (such as the camel adapting to constantly arid conditions). Intelligence on the other hand is the evolutionary solution to the problem of an environment that shifts faster than natural selection can adapt the body. So for there to have been a strong evolutionary pressure driving hominins to ever more flexible and intelligent behaviour, something must have been affecting our ancestors over very short timescales.

What might have been special about the circumstances in East Africa that drove evolution towards highly intelligent hominins such as ourselves? The answer that has been emerging in recent years comes down once again to the peculiar tectonic environment of the region. As we have seen, East Africa was bulging upwards with the magma plume rising beneath and this stretched the crust until it fractured and faulted. The geography of the Great African Rift is therefore characterised by a flat valley floor where great chunks of crust have sunk down, and which is lined on both sides by mountainous ridges. In particular, from about 3 million years ago numerous large, isolated basins formed on the valley floor that could fill with lakes if the climatic conditions were wet enough.[26] These deep lakes are important because they provided hominins with a more reliable source of water through the dry seasons each year than that supplied by streams.[27] But many of them were also ephemeral: they appeared and disappeared over time with the shifting climate.



The East African rift valley system, with major lakes and amplifier lake basins shown.

The landscape of the tectonic rift creates a sharp contrast in the conditions between the high ground and the bottom of the valley. Rain falls over the tall rift walls and volcanic peaks, where it then flows into the lakes dotting the valley floor, a much hotter environment with high rates of evaporation. This means that many of the lakes in the Rift Valley are exceedingly sensitive to the balance between precipitation and evaporation, and even a slight shift in climate causes their water levels to respond very considerably and rapidly – far more so than other lakes around the world and even elsewhere in Africa.[28] As small changes in the regional climate cause very large changes in the levels of these vital bodies of water, they are known as 'amplifier lakes' – they act like a hi-fi amplifier intensifying a weak signal. And it is these peculiar amplifier lakes that are thought to provide the key link between the long-term trends of tectonics creating the rift valley and the Earth's climate swings and the rapid fluctuations of habitats that directly, and dramatically, affected our evolution.

Two particular aspects of our planet's cosmic circumstances are important here: the stretching of Earth's orbit around the Sun (eccentricity) and the gyration of the Earth's axis (precession). Every time Earth's orbit was pulled into a more elongated shape (maximum eccentricity) the climate in East Africa became very unstable. During each of these phases of climatic variability, whenever the precession cycle cast a little more solar warming onto the Northern Hemisphere, more rain fell onto the walls of the Rift Valley. The amplifier lakes appeared and enlarged, their shores lined with woodland. And conversely, during the opposite phase of the precession cycle the rift received less rainfall and the lakes diminished or disappeared altogether. The Rift Valley then returned to an extremely arid state with minimal foliage.[29] So overall, the environment in East Africa over the last few million years has largely been very dry, but this general state was interspersed with highly variable periods when the climate swung rapidly back and forth between being much wetter and then very arid again.

These variable phases occurred every 800,000 years or so, and during those periods the amplifier lakes flickered in and out like a loose lightbulb – each swing causing a considerable shift in the availability of water, vegetation and food, which had a profound influence on our ancestors. The rapidly fluctuating conditions favoured the survival of hominins who were versatile and adaptive, and so drove the evolution of larger brains and greater intelligence.[30]

The three most recent periods of such extreme climatic variability occurred 2.7–2.5, 1.9–1.7, and 1.1–0.9 million years ago.[31] Looking at the fossil record, scientists have made a fascinating discovery. The timing of when new hominin species emerged – often associated with an increase in brain size – or fell extinct again, tends to coincide with these periods of fluctuating wet–dry conditions. For instance, one of the most important episodes in human evolution occurred in the variable period between 1.9 and 1.7 million years ago, a phase when five of the seven major lake basins in the rift repeatedly filled and emptied. It was during this time that the number of different hominin species reached its peak, including the emergence of *H. erectus* with its dramatic increase in brain size. Overall, of the fifteen hominin species we know of, twelve first appeared during these three variable phases.[32] What's more, the development and spread of the different stages of tool technologies that we discussed earlier – Oldowan, Acheulean, Mousterian – also correspond with the eccentricity periods of extreme climate variability.[33]

And not only did the variable periods determine our evolution, they are also thought to have been the force driving several hominin species to migrate out of their birthplace and into Eurasia. We'll explore in detail in the next chapter how our species *Homo sapiens* were able to disperse around the entire globe, but the conditions propelling hominins out of Africa in the first place again lie with the climate fluctuations in the Great Rift.

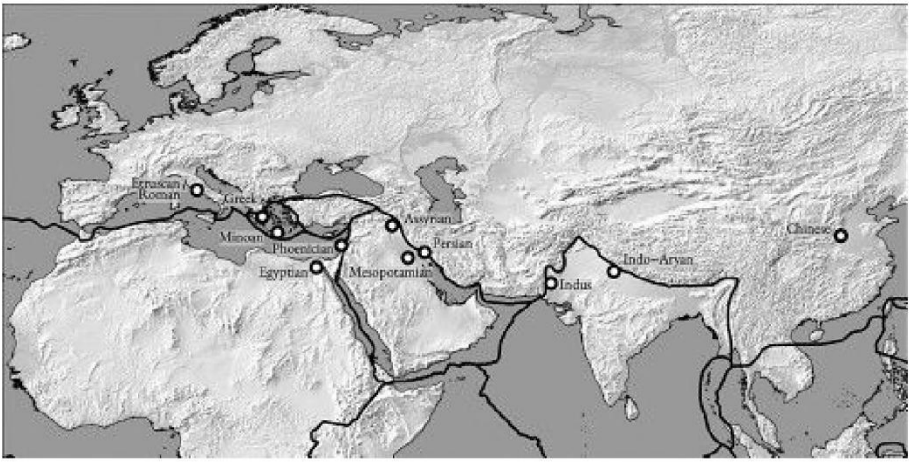
tectonics of East Africa ripped open the Rift Valley to create a particular geography of tall walls collecting rainfall and a hot valley floor. Cosmic cycles in Earth's orbit and spin axis periodically filled basins on the rift floor with amplifier lakes that responded rapidly to even modest climate fluctuations to create a powerful evolutionary pressure on all life in this region.

These unique circumstances of our hominin homelands drove the development of adaptable and versatile species. Our ancestors came to rely more and more on their intelligence and on working together in social groups. This diverse landscape, varying greatly across both space and time, was the cradle of hominin evolution, and out of it emerged a naked and chatty ape smart enough to come to understand its own origins. The hallmarks of *Homo sapiens* – our intelligence, language, tool use, social learning and cooperative behaviour, which would allow us to develop agriculture, live in cities and build civilisations – are consequences of this extreme climatic variability, itself produced by the special circumstances of the Rift Valley. Like all species, we are a product of our environment. We are a species of apes born of the climate change and tectonics within East Africa.[38]

WE ARE THE CHILDREN OF PLATE TECTONICS

Plate tectonics did not just create the diverse and dynamic environment of East Africa in which we evolved as a species; they were also to be a factor that defined where humanity embarked on building our early civilisations.

If you look at a map of the tectonic plate boundaries grinding against each other and superimpose the locations of the world's major ancient civilisations, an astonishingly close relationship reveals itself: most are located very close to plate margins. Considering the amount of land available for habitation on Earth, this is a startling correlation, and is very unlikely to have come about by chance. Early civilisations seem to have chosen to snuggle up close to tectonic fractures, millennia before scientists identified their existence. There must be something about the plate boundaries that made them so favourable for the establishment of ancient cultures, despite the dangers of earthquakes, tsunamis and volcanoes posed by these fractures in the Earth's crust.



Major early civilisations and their proximity to plate boundaries.

In the Indus Valley, the Harappan civilisation emerged around 3200 BC as one of the three earliest in the world (alongside those in Mesopotamia and Egypt),[39] in a depressed trough running along the foot of the Himalayas. The collision between tectonic plates creases up ranges of high mountains – such as the Himalayas, created by the crashing of India into Eurasia – but the immense weight of the mountain range also flexes the crust alongside it downwards to create a low-lying subsiding basin. The Indus and Ganges rivers flowing off the Himalayas run through this foreland basin, where they deposit sediment eroded from the mountains to produce very fertile soils for early agriculture. You could say that the Harappan civilisation was born of the continental collision between India and the Eurasian plate.

In Mesopotamia, the Tigris and Euphrates rivers also flow along a subsiding foreland basin, pushed down by the Zagros mountains that formed as the Arabian plate was subducted beneath the Eurasian (shown here).[40] Mesopotamian soils were therefore similarly enriched with sediment eroded out of this mountain range.[41] The Assyrian and Persian civilisations both arose right on top of this junction between the Arabian and the Eurasian plate.

The Minoans, Greeks, Etruscans and Romans all also developed very close to plate boundaries within the complex tectonic environment of the Mediterranean basin. Within Mesoamerica, the Mayan civilisation emerged from around 2000 BC and spread across much of south-eastern Mexico, Guatemala and Belize, with major cities built among the mountains raised by the subduction of the Cocos plate beneath the North American and Caribbean plates. And the later Aztec culture flourished close to the same convergent plate boundary, with its earthquakes and volcanoes like Popocatepetl, the 'Smoking Mountain', sacred to the Aztecs.[fn5]

And it is not just depressed basins at the feet of mountain ranges raised by continental collisions, like Mesopotamia, that hold rich arable land. Volcanoes also produce fertile agricultural soil. They arise in a broad line 100 kilometres or so away from the subduction line, as the swallowed plate sinks deeper into the hot interior and melts to release rising bubbles of magma to feed eruptions on the surface above. Civilisations in the Mediterranean, such as the Greek, Etruscan and Roman, arose in areas of rich volcanic soil in the band where the African plate is being subducted under the smaller plates making up the Mediterranean region.[42]

Tectonic stresses also hold open fractures in rocks or push up blocks of crust in what is known as a thrust fault, which often create water springs. The long line of linked mountains along southern Eurasia, crumpled up by the collision of the African, Arabian and Indian plates, happens to coincide with the arid band across the Earth's surface. This includes the Arabian and Great Indian deserts, and is created by the dry, descending portion of circulation in the atmosphere (which we'll come back to in Chapter

8). Here these thrust faults frequently lie at the junction between low-lying barren deserts and high-rising inhospitable mountains or plateaus, and so trade routes often pass along these geological boundaries. Towns dotted along the way accommodate the travelling merchants, supported by the water springs at the foot of the mountains.[43] But while tectonic movements can provide water sources in otherwise arid environments, these settlements are also vulnerable to destructive earthquakes with each new slip of the crust.[44]

In 1994 the small desert village of Sefidabeh in south-eastern Iran was utterly destroyed by an earthquake. The curious thing was that Sefidabeh is exceedingly remote: one of the few stops on a long trade route to the Indian Ocean, it's the only settlement for 100 kilometres in any direction. And yet the earthquake seemed to target the village with uncanny precision. It turns out that Sefidabeh had been built right on top of a thrust fault lying far underground. The fault was so deep that it had created no obvious signs of its existence on the surface, such as a tell-tale scarp, and so hadn't been previously identified by geologists. In hindsight, the only sign was an unremarkable, gently-folded ridge running alongside the town, that had slowly been built up over hundreds of thousand years of earthquake movements. The settlement had grown here because this continual tectonic up-thrusting maintained springs at the base of the ridge – the only water source for miles around. The tectonic fault had created the conditions allowing life in the desert, but it also had the potential to kill.[45]

The sources of water provided by these thrust faults have been used for thousands of years, and explain the location of many ancient settlements on tectonic boundaries. They are becoming an increasing cause for concern in the modern world, however. The capital of Iran, Tehran, began as a cluster of small towns on a major trade route at the base of the Alborz mountain range. The city grew rapidly from the 1950s and today is densely populated with a permanent population of over 8 million residents, rising to over 10 million during working hours.[46] But the small trading towns originally occupying this site through the centuries were repeatedly damaged or levelled outright by the jerk of earthquakes as this thrust fault shifts to relieve mounting tectonic stress. The city of Tabriz, further along the mountain chain to the north-east of Tehran, was devastated by earthquakes in 1721 and 1780, each killing more than 40,000 people at a time when the population of any city was only a tiny fraction of what it is today. If, or indeed when, another large earthquake jolts on this thrust fault, the effects on Tehran could be devastating. People have settled at such thrust faults for millennia, drawn by the water supply they create and the trade routes running along the landscape boundary, and the large modern cities that have developed here are now particularly vulnerable from this geological heritage.[47]

We are the children of plate tectonics. Some of the largest cities in the world today rest on tectonic faults, and indeed many of the earliest civilisations in history emerged along the boundaries of the plates that make up Earth's crust. And more fundamentally, tectonic processes in East Africa were critical for the evolution of hominins and the forging of our particularly intelligent and adaptable species. Let's turn now to the peculiar period of our planet's history that enabled humanity to migrate from our birthplace in the Great Rift Valley and come to dominate the entire globe.

drier. Howling winds drove fierce dust storms across the arid plains.[7] Much of Europe and North America's landscape would have been tundra-like, with the underlying soil frozen all year round (permafrost), and dry, grassy steppes stretching as far as the eye could see further south. Many of the trees that grow across Europe today survived only in isolated refuges around the Mediterranean. Twenty thousand years ago, the dense forests and woodlands of today's Central Europe would have instead resembled present-day Northern Siberia.[8]

With the end of each ice age, the oceans rose again and flooded the continental shelves. The returning interglacial climate saw the ecosystems around the world slowly spread back towards the poles, following the ameliorating conditions behind the retreating ice sheets. Migrations are common within the animal world – birds flying south for the winter or the great herds of wildebeest surging like a tide across the Serengeti – but forests also migrate. Of course, individual trees cannot uproot and move, but as the climate gets warmer, seeds and saplings survive a little further north each year, and over time the forest genuinely marches (like the prophecy in *Macbeth*). After the last ice age, tree species in Europe and Asia are estimated to have migrated north at an average rate of over 100 metres every year.[9] Animals followed them – herbivores feeding directly on plants and the predators in turn tracking them. Recurring ice ages have forced the movement of plant and animal life to sweep north and south like a living tide.

Ice ages vary in their intensity, and interglacial periods are also not all alike.[10] The last interglacial, which occurred about 130,000–115,000 years ago, was generally warmer than our current one. Temperatures were up at least 2 °C from today, sea levels around 5 metres higher, and the sort of animals you would normally associate with Africa were tramping through Europe. When construction workers were digging in Trafalgar Square in the centre of London in the late 1950s, they discovered the remains of