TRANSCENDENCE

How Humans Evolved through Fire, Language, Beauty and Time

'A wondrous, visionary work'
Tim Flannery

GAIA VINCE

PENGUIN BOOKS

TRANSCENDENCE

'A beautifully imaginative overview of the biological and cultural evolution of humans. Richly informed by the latest research, Gaia Vince's colourful survey fizzes like a zip-wire as it tours our species' story from the Big Bang to the coming age of hypercooperation'
Richard Wrangham, author of *The Goodness Paradox*

'The storming success of Yuval Noah Harari's books has inspired many others that aim to span the epic sweep of human history with grand theories and cor-blimey factoids. This book does both well. Gaia Vince shows how humans transcend their origins to become world-conquering apes' *The Times*, Books of the Year

'Vince draws on extensive travels and many interviews with scientists to offer vivid accounts of these forces at work in the lives of our "cultural forebears". A provocative, highly readable take on our astonishing emergence from the primordial soup'
Kirkus Reviews

'An imaginative and inspiring adventure into the origins and evolution of what we hold most dear: our human culture'
Uta Frith, Emeritus Professor of Cognitive Development UCL

'This book goes from the Big Bang to the Hundred Thousand Genome Project to make a convincing case that *Homo sapiens* has become a super-organism. I learned a lot from it and so will you'
Steve Jones, author of *Almost Like a Whale*

'Gaia Vince's enthralling second book, ideal for anyone who loved *Sapiens*, shows how a unique combination of genes, environment and culture (from our love of objects to our knowledge of mortality) has enabled us to determine our own destiny, uniquely among species on earth'
Bookseller

'Even those broadly familiar with humanity's story will find new information and insights in Vince's fascinating study'
Publishers Weekly

'Any story that begins with the words '14 billion years ago' is bound to be epic, and *Transcendence* is no exception. An impressive breadth of research from paleoarchaeology to genetics to anthropology'
M. R. O'Connor, *Undark*

ABOUT THE AUTHOR

Gaia Vince is a science writer and broadcaster interested in the interplay between humans and the planetary environment. She has held senior editorial posts at *Nature* and *New Scientist*, and her writing has featured in newspapers and magazines including the *Guardian*, *The Times* and *Scientific American*. She also writes and presents science programmes for radio and television. Her research takes her across the world: she has visited more than sixty countries, lived in three and is currently based in London. In 2015, she became the first woman to win the Royal Society Science Book of the Year Prize solo for her debut, *Adventures in the Anthropocene: A Journey to the Heart of the Planet We Made*. She blogs at WanderingGaia.com and tweets at @WanderingGaia.

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For my parents,
whose fault it all is
by nature or nurture

Contents

Introduction

When Neil Harbisson went to renew his UK passport in 2004, there was a problem with the photograph he had provided. It should contain 'no other people or objects. No hats, no infant dummies, no tinted glasses'.

The regulations didn't say anything about antennae.

Nevertheless, he was told to remove the accessory from his head and resubmit his application. Harbisson explained that his antenna was not an accessory, but a part of him – 'an extension of his brain' – and anyway, he couldn't remove it as it had been surgically implanted. The passport was issued.

That is how Harbisson became the world's first officially recognized cyborg.

Harbisson describes himself as the first 'trans-species' person. Through a technological adaptation he has evolved into something else – something beyond a biological human, something beyond nature.

Harbisson now has extrasensory perception: he can hear colours through his antenna. He had been born a biologically compromised human, unable to see in colour, as the result of a rare genetic condition called achromatopsia. Through his eyes, the world appears in shades of grey. As a 21-year-old art student, he collaborated with a couple of software programmers and a musician to develop an electronic device that would allow him to sense colours as musical notes and chords. In 2004, after a difficult search, he found a doctor who, on condition of anonymity, would implant the device.

The antenna is a black flexible wand that emerges from somewhere under his straw-blond hair at the back of his head, and protrudes up and over his forehead. Harbisson wears his hair in a severe bowl-shaped cut, shaved up at the back, so that it resembles a helmet, further blurring the line between the biological and artificial. At the front of the antenna is an electronic 'eye' that detects the colours of the objects around him and transmits these light frequencies to a chip implanted in his skull. There, these impulses are converted to sound frequencies and Harbisson hears the colours of the world through the bones of his head.

Initially, he struggled to make sense of the overwhelming colour information flooding his mind, and to discern and distinguish colour sounds by their names. But, 15 years on, he lives in a fabulous Technicolor symphony – he even dreams in colour. His biological brain has merged so completely with the electronic software that he now experiences sounds, speech, bleeps and other noise as colour. He began painting people's voices and musical compositions, from Mozart to Lady Gaga. Then he decided to expand his palette beyond the human range. Now, Harbisson can perceive ultraviolet and infrared, so that he can 'see' objects in the dark, appreciate patterns invisible to the rest of us unenhanced humans, and can even spot the UV markers left on tree trunks that animals produce in their urine. He has also upgraded his chip to allow Internet access, so he can connect to satellites and receive colours from external devices. It's an organ that is still evolving, Harbisson says.

In 2018, he had compass components fixed inside his knees to allow him to sense the earth's magnetic field, and his next implant will be a crown-like device he has designed, which he describes as an organ for time. It will span his head, producing a heat spot that will revolve around his skull in 24-hour cycles, allowing him to perceive time – to, in effect, sense the earth's rotation. Once his brain has accepted and integrated the new organ, Harbisson hopes to be able to stretch or speed his perception of time by altering the speed of the heat spot's motion. If he wants a moment to last longer, for example, he will be able to slow the heat motion. In this way, he might even be able to change his sensation of ageing, manipulating his relative experience of time, to live to 170. 'In the same way that we can create optical illusions, because we have an organ for the sense of sight, I think we can create time illusions if we have an organ for the sense of time,' he explains.

The term 'cyborg' was coined in 1960* by American scientists Manfred Clynes and Nathan Kline, who were describing their vision of an enhanced human that could survive in an extraterrestrial environment. Now, this fiction has become reality for Harbisson, and also for the hundreds of millions of people who rely on contact lenses, cochlear implants, artificial heart valves, and a range of other bionic aids to enhance their natural abilities. Whether integrated into our bodies or not, our tools and gadgets give us exceptional powers: we can fly without wings, dive without gills, be resuscitated after death, escape our planet to set foot on the moon. More prosaically, they are the blades that improve on our teeth and nails' ability to cut our food and the soled shoes that help our feet run fast on stony ground. In truth, we are all cyborgs, for none of us can survive without our technological inventions.

But to think of us simply as a sort of smarter chimp with cool tools is to miss what is truly extraordinary about us and the way we operate on this planet. Yes, we have evolved incredibly diverse and complex gadgets, but so too have we evolved languages, artworks, societies, genes, landscapes, foods, belief systems and so much more. Indeed, we have evolved an entire human world – a societal operating system – without which Harbisson's antennae would not only not exist, but also be pointless. For it is our human world that gives our technologies meaning and drives their invention. We are so much more than evolved cyborgs.

I presume you are not reading this while perched naked in a tree in the Congo jungle. You are, like me, wearing clothes, processed from plants grown thousands of miles away, woven, dyed, cut and stitched by different hands, aided by several machines, to somebody's design somewhere else, shipped to another place, priced and marketed by other people, working to various orders, and eventually, several steps later, of your own unique volition, wrapping your skin as wonderfully as fur. Perhaps you are sitting on a plastic chair formed out of the processed carcasses of long-dead sea creatures, held up by steel legs generated from mined rocks, blasted and refined and assembled in multiple steps by teams of people independently fashioning a structure that was devised and altered over millennia, millions of times.

* The idea is at least a century older, though: in 1843, the horror writer Edgar Allan Poe described a man with extensive prostheses.

Wherever you are, you are generating in your mind these words that I have written as though I were speaking them into your ear. My mind is directly connecting with your mind now, even though I wrote this in another time and place, perhaps in another language. It's possible that I'm no longer even alive.

You are smart but, when alone, you are fairly powerless. We live our lives utterly dependent on countless strangers for our survival. Men and women have toiled to make and assemble the constituents of my lunch, clothes, furniture, house, road, city, state and world beyond me. These many cooperating, collaborating strangers have themselves relied on thousands upon thousands of other people, living and dead, to shape the lives they lead. And yet there is no contract, no plan and no common purpose to our 7 billion lives.

If it seems incredible that everything we see now – all the busyness and industry of billions of people living seemingly autonomous yet utterly interdependent lives – could have arisen without any plan, then consider this: our superb working body, from its eyes to its toenails to its consciously aware brain, emerged similarly from a single cell, in a matter of weeks. As a fertilized egg cell begins to grow and divide, the one cell becomes a mass of pluripotent cells, meaning they have the potential to be any type of cell in the body, depending on their biological developing bath. Thus, a cell that finds itself by chance on the outer part of the ball may end up developing into a nerve cell in the spinal cord; another cell, depending on its developing bath, will become a heart cell. Evolution has created a mechanism whereby a functioning system of cooperating organs and cells – a human being – can be built from a simple cell.

We are each of us individuals with our own motivations and desires, and yet much of our autonomy is an illusion. We are formed in a cultural 'developing bath' that we will ourselves then fashion and maintain – a grand social project without direction or goal that has nevertheless produced the most successful species on Earth.

Humans now live longer and better than ever before, and we are the most populous big animal on Earth. Meanwhile, our closest living relatives, the now endangered chimpanzees, continue to live as they have for millions of years. We are not like the other animals, yet we evolved through the same process. What are we then?

This question fascinated me and I set out to understand our exceptional nature and what alchemy created humanity – this planet-altering force of nature – out of an ape.

What follows is a remarkable evolution story that has captivated me utterly. It all rests on a special relationship between the evolution of our genes, environment and culture, which I call our human evolutionary triad. This mutually reinforcing triad creates the extraordinary nature of us, a species with the ability to be not simply the objects of a transformative cosmos, but agents of our own transformation. We have diverged from the evolutionary path taken by all other animals, and, right now, we are on the cusp of becoming something grander and more marvellous. As the environment that created us is transformed by us we are beginning our greatest transcendence.

Let me explain.

We are Earthly beings – Earth-conceived and Earth-born. The role of our planetary home in making a species that would itself reshape that planet is little appreciated, and yet the environment made us the people we are today. After all, it is in response to our environment that we walk on two legs, speak tonal languages, have immunity to the flu virus and developed culture. So, my story begins with the geological origins of our *Genesis*. All life is formed of the stuff of the universe, and we humans are fundamentally a microcosm of the grand cosmos. The calcium in the limestone cliffs supporting our coastlines is also in the bones that support us internally – both owe their provenance to the stars. The water coursing through our planet's rivers, much like our internal rivers of blood, has its origin in comets.

Humans emerged, like every other life form, through the process of biological evolution. Species change over time because randomly occurring genetic differences accumulate within populations over generations. Organisms whose genes make them more successful in their environment are more likely to survive and reproduce, thus passing their genes to subsequent generations. In this way, biology adapts in response to environmental pressures, and species have gradually evolved to exploit every habitat on Earth.*

* Living beings also respond and adapt to environmental challenges during their lives with physiological and behavioural changes, most of which are genetically programmed, inherited and instinctive.

Our intelligent, social ancestors also evolved adaptations to survive in their environment, which, for our early hominid forebears, was a tropical forest habitat, and one of these adaptations was culture. 'Culture' has so many different interpretations, but when I use the term, I am referring to learned information expressed in our tools, technologies and behaviours. Human culture relies on our ability to learn from others and to express this knowledge ourselves. We are not the only species to have evolved culture, but ours is far more flexible: it is cumulative and it evolves. Human cumulative culture ratchets up in complexity and diversity over generations to generate ever more efficient solutions to life's challenges.

Cumulative cultural evolution has proven a game changer in the story of life on Earth. Instead of our evolution being driven solely by changes to environment and genes, culture also plays its part. Cultural evolution shares much with biological evolution. Genetic evolution relies on variation, transmission and differential survival. All three are there with cultural evolution. The main difference is that, in biological evolution, they are operational mostly at the level of the individual, whereas for culture, group selection is more important than individual selection, as we shall see. It is our collective human culture, even more than our individual intelligence, that makes us smart.

We weren't the only human species to go down this evolutionary route – and we will visit our cousins – but we are the only ones to have survived. Hundreds of thousands of years ago, we began to escape our original environmental cradle by using our culture to overcome the physical and biological limitations that trap other species into uncreative lives. Our extraordinary evolution is driven by four key agents, which I describe in the following sections: *Fire*, *Word*, *Beauty* and *Time*.

Fire describes how we outsource our energy costs to escape our biological limitations and extend our physical capabilities. *Word* investigates the role of information in our success: the use of language to accurately transmit and store complex cultural knowledge and communicate ideas between minds. Language is a social glue that binds us with joint stories, and enables us to make better predictions and decide who to trust based on their reputations. *Beauty* encapsulates the importance of meaning in our activities, which enables us to coalesce around shared beliefs and identities. Our artistic expression produces cultural speciation – tribalism between and within our societies – but also enables the trade in resources, genes and ideas that prevents genetic speciation, while leading to bigger, better-connected societies with fancier technologies. Lastly, *Time* underlies our quest for objective, rational explanations for natural processes. The combination of knowledge and curiosity has driven us further than any other animal: we've developed the science to order the world and our place in it, becoming a connected global humanity.

It is the interweaving of these four threads that creates the extraordinary nature of us and explains how we operate as we do: why people who live in cities are more inventive, why religious people are less anxious, why Filipino storytellers have more sex, why migrants have a greater risk of schizophrenia, why Westerners see faces differently from East Asians. The human evolutionary triad – genes, environment and culture – are all implicated. For instance, the probability that any two of your friends are friends with each other – known as network transitivity – affects your individual fate, as well as the performance of the group.[1] But transitivity is influenced by environment – isolated villages have higher transitivity (everyone knows each other). On top of this, the number of friends you have is influenced by your genes.[2] The majority of all of this comes down to chance: who, where and when you were born is likely to be much more important than any choice you will ever make.

This is a great time to be exploring such fundamental questions about how we became such an extraordinary species. Exciting advances in population genetics, archaeology, paleontology, anthropology, psychology, ecology and sociology are beginning to reveal new insights into our history, fundamentally changing our understanding of how we developed as a species. For instance, the idea that a so-called behaviourally modern human emerged just 20 (or 40) thousand years ago, through some sort of cognitive or genetic revolution, is being challenged. The first individual human genome was sequenced in 2007, and since then, thousands of people have had their unique genetic history decoded and, in doing so, helped us understand our collective history – how we are related and how we relate to our closest human cousins.

Meanwhile, archaeologists using new dating techniques have made astonishing discoveries about our most ancient artworks and technologies, and paleontologists have shown the textbook tale of the simple ascent of man to have been anything but simple.

We are also entering a new era of collaboration: for the first time, many people from these famously protectionist research fields are beginning to talk to each other, upsetting well-established dogma but generating a wealth of data, insight and experience. This meeting of the natural sciences and the social sciences is starting to resolve this central paradox of why we are biologically so very similar and yet behaviourally so very different. We are looking at ourselves with new eyes, and recognizing the deep links that run through our biology, culture and environment.

As we will discover, human cultural evolution allows us to solve many of the same adaptive problems as genetic evolution, only faster and without speciation. We are continually making ourselves through this triad of genetic, environmental and cultural evolution; we are becoming an extraordinary species capable of directing our own destiny. It is this that has allowed us to expand our population size and geographical range, in turn accelerating our cultural evolution to greater complexity in a mutually reinforcing cycle.

Today, the size and connectedness of our populations have reached unprecedented levels. At the same time, we have produced a dramatic shift in Earth's environment, pushing the planet that formed us into an entirely new geological era known as the Anthropocene, the Age of Humans. The accumulation of our material changes alone – including roads, buildings and croplands – now weighs an estimated 30 trillion tons and allows us to live in an ultraconnected global population that's headed for 9 or 10 billion people.* Look around you: we are the intelligent designers of all you see. There is no part of Earth untouched by us – we're even littering space.

I'm going to take you on a journey to show how our uniquely human attributes changed us as a species – and how, in so doing, they reset our relationship with nature.

* Without this artificial habitat we would be reduced to a Stone Age population of no more than 10 million.

We are now, all of us, on the brink of something quite exceptional. The interplay of human culture, biology and environment is creating a new creature from our hypercooperative mass of humanity: we are becoming a superorganism. Let's call him *Homo omnis,* or Homni for short.

This is the story of our transcendence.

GENESIS

Every culture has its own creation myth to explain our origins, to make sense of the incredible unlikeliness of a talking ape that is curious enough to invent fantastical stories about how it came to be. The truth is no less remarkable.

Look up at the stars. You are not seeing them as they are now, but as they were millions of years ago. With your human eyes you are looking back in time, receiving light and imagery sent before our species existed, enjoying something perhaps long since extinguished.

We use history to look back at where we've come from. We also need science, because who we are is made from what we were before. Just as you might trace the origins of your cheek dimple to your great-grandmother, or find the basis for your country's politics in an ancient battle, so we must journey back through our ancestry to understand the origins of the structures, technologies and behaviours that drive our human world today.

Ultimately, this reveals our deep connections to our ancestor the sun. Our genesis is a story of physics, chemistry and biology that produced something that could control all three. Every one of us, everything on Earth, Earth itself, all the stars and galaxies in the universe, are deeply connected, and that connection goes back to a single point 13.8 billion years ago.

1

Conception

Fourteen billion years ago, the Big Bang created just enough of an excess of matter over antimatter for the existence of everything that we see in the universe today.

Entirety exploded out of something as contained as a quantum dot, and it has been expanding into glorious disorder ever since. Here on Earth, the only known living beings in the Universe attempt to do battle with entropy, create order out of chaos, building complex structures from energetic particles.

Energy generated matter, and that's made of atoms. Whether these crumbs make up a lump of iron, or an elephant's ear, or the scent of a rainforest depends on the number of protons at its heart: a hydrogen atom has just one proton, whereas lead has 82. But it is how the atoms transfer energy that determines much of the difference between hydrogen and lead (and their usefulness to us), and that is determined by their electrons, which spin outside the atom's nucleus and obey the strange rules of quantum mechanics.

The energetic exchanges made every time an electron moves within or between atoms are the basis for every reaction on Earth, from the replication of DNA to the laughter of a baby. It is the electrons embedded in our breakfast porridge that later provide us with the energy to chew our sandwich at lunch. These electron shifts allow atoms to combine chemically to form molecules, which are the building blocks of living cells, and so of us.

Around 90 per cent of all matter in the universe is hydrogen; another 5 per cent is helium, an unreactive atom with two protons. Both were produced in the instants after the Big Bang. As the stars shine, they fuse hydrogen atoms together into the heavier elements of our world, including oxygen, carbon and nitrogen, which are extremely rare in the universe but make up most of the human body. And the violent drama that birthed the stuff of us also produced the elements we prize most. If you are wearing a piece of gold jewellery, know that you are likely to be wearing the celestial debris of a cataclysmic stellar collision so devastating that it literally shook the universe.

Gravity pulled together the interstellar clouds of hydrogen, helium and dust – the nebulae – with such force that their nuclei fused, releasing enormous amounts of energy and a new generation of stars. The star most important to our story, the sun – a nuclear reactor burning hydrogen in a cloud of cosmic dust – was born 4.6 billion years ago. Out of its dirty halo, a spinning clump of minerals coalesced: Earth, the third rock from the sun. Soon after, a massive asteroid crashed into our planet, shaved off a huge chunk – creating our moon – and knocked the world on to a tilted axis. That tilt gave us seasons and currents, and the moon's influence birthed our oceans' tides. Earth's position, the pull of Jupiter[1] and our orientation from the sun all played their part in creating a crucible for the greatest experiment in the universe.

Just one in 3 million of the molecules of Earth is water, but they are concentrated at the surface, and that makes all the difference. The ingredients for DNA, amino acids, rained down from comets, combined with the elements on Earth and kick-started life's incredible genesis in the planet's oceans some 4 billion years ago. At the nanoscale of atoms, where the masses involved are so small that the force of gravity becomes irrelevant, intermolecular forces such as electrostatic charges of attraction and repulsion dominate. One of the most surprising observations is that certain chemical processes become self-replicating. In this way, single molecules of DNA multiply, creating new life. Did the miracle happen just once or several times? We may never know for sure, but from one cell of self-copying magic evolved the incredible diversity of life that includes us, humans who have bitten the apple of knowledge and can now create nature itself.

Evolution has no aim and no direction – the ability to see, to walk, to fly, have variously arisen in creatures and been lost – but complexity takes time: billions of years of biological – and environmental –

evolution occurred before anything resembling us emerged. Initially, there was nothing to breathe, as the world's first atmosphere consisted of hydrogen and water vapour. It took around 2 billion years for the gas of life to pervade the air, courtesy of ancient blue-green algae, which used the energy from sunlight to make sugars from carbon dioxide, and in the process released oxygen as a waste product.

Photosynthesis and respiration, volcanic eruptions and tectonic movements, the tilt of the planet near or far from the sun – they all continually changed the balance of warming carbon dioxide and life-giving oxygen in the atmosphere, altering the climate as well as the chemistry and biology of the oceans. Over its first 3.5 billion years, the planet swung in and out of extreme glaciation. When the last ended, there was an explosion of complex multicellular life forms.

The emergence of life on Earth fundamentally changed the physics of the planet, and transformed it into a living, breathing system. When plants evolved, they sped up the slow breakdown of rocks with their roots, helping to erode the channels that would become our rivers. Photosynthesis imbued the Earth system with chemical energy, and when animals ate the plants, they modified this chemistry, releasing warming carbon dioxide and, with their death, contributing sedimentary layers to the original rock.

In return, the physical planet dictated Earth's biology, for life evolves in response to geological, physical, and chemical conditions. In the past 500 million years, there have been five mass extinctions triggered by supervolcanic eruptions, tectonic shifts, asteroid impacts and other enormous climate-changing events. After each, the survivors regrouped, proliferated and evolved as the Chinese whispers of random genetic mutations passed down the generations. The environment applies an evolutionary pressure on life, which selectively adapts – and it's been a two-way process: If plants became better at surviving in the desert (with genetic changes), they in turn changed the desert into less arid scrubland or dry forest. And this influenced which species (and which genes) could survive there.

There was no inevitability to our existence – to the existence of intelligent life – even if, looking back along our evolutionary route, it seems almost directed. Just an immeasurable rain of chance occurrences, big and small, splattering and splashing and, over the eons, trickling to unpredictable consequences: the delightful possibility of puzzle-solvers as different as an octopus and a human sharing space and time.

We can thank the heavens for our biggest evolutionary break. One day, in late June,[2] 66 million years ago, a meteorite so massive that it dwarfed Mount Everest, travelling at 14 kilometres per second (20 times faster than a bullet), plunged into the Yucatan Peninsula in present-day Mexico.[3] The impact was so extreme, so rapid, that the meteorite reached Earth still intact, exerting a pressure wave on the atmosphere in front of it that was so intense it began excavating the crater before the space rock even hit. On impact, the asteroid punched a 20-mile hole into the ground, deep enough to pierce the Earth's mantle, and sent shock waves across the planet that generated volcanic eruptions, earthquakes, landslides and blizzards of fire. What life survived the impact was mostly wiped out by the punishing global climate change that followed. Dinosaurs, which had dominated Earth for millions of years, disappeared; this ecological vacancy was filled by our mammal ancestors.

Some 10 million years later, rapid climate change turned the world humid, and tropical rainforests, palms and mangroves spread as far north as England and Canada, and all the way to New Zealand in the south. The Arctic Ocean was a balmy 20-something degrees Celsius but stagnant. Sea levels rose globally, and there were mass migrations and extinctions of animals and plants. Mammals diversified and the forerunners of many of today's common species emerged, including the first true primates. Then, around 20 million years ago, the Indian and Asian tectonic plates collided, buckling the land above so severely that the vast mountains of the Himalaya were created and the massive Tibetan Plateau uplifted, in a process that continues today. This new geography had a dramatic impact on the region's climate and biology: it divided the world's ape species into what would become Old and New World lineages, and produced new weather patterns, including the Southeast Asian monsoon. Meanwhile, volcanic activity beneath the Horn of Africa was tearing a great north–south rift down the eastern side of the continent, generating mountains with a raised valley between them, a process that fragmented the landscape and changed the climate. Evolutionary opportunities flourished in such dramatic environmental change.

We can trace our excellent colour vision to this time, when our foraging primate ancestor acquired the genetic mutation for an extra (third) eye cone cell, which enabled it to additionally see reds – most monkeys are limited to seeing in blues and greens. This helped with avoiding poisonous plants and distinguishing ripe fruits, which contain more calories, are easier to digest, and require less energy. Better nutrition allowed the growth of bigger brains; fruit-eating primates have 25 per cent more brain tissue than plant-eating primates.[4]*

Our ancestral habitat switch from forests to the savannah was another key turning point in our evolution. Its roots lie in a geological event 3 million years ago, when the drifting South American continent crashed into the North American continent at what is now Panama. This rerouted the ocean currents, dividing the Pacific Ocean to create on the east the Atlantic and Caribbean Sea. Warm waters from the tropics were pushed up toward the Arctic, where they cooled and descended down and south in a planet-spanning loop known as the Global Ocean Conveyor, which today dominates much of the world's climate. That led to the formation of the Gulf Stream, provided the moisture to freeze the Arctic, created a series of ice ages, and reset rainfall patterns, which dried East Africa and created new savannah landscapes.

Over the hundreds of thousands of years that our ancestors' bodies adapted to the savannah, climate change also reduced their former forest habitat. They had to spend many hours chewing roots and bulbs for protein, because there are no fruits on the savannah for much of the year, and increasingly relied on their social group for support. This particular orchestration of self-replicating chemicals had become a species ready to begin the process of self-domestication.

* The environmental role in seemingly unconnected biological traits, such as intelligence, is easy to overlook, but consider that plants evolved genetic adaptations that cause their fruits to redden and sweeten as they ripen (to attract animals that will spread their seeds). And primates evolved genetic adaptations in response to this environmental buffet. The environment shapes us and we shape it.

2

Birth

The immense limestone monolith of Gibraltar rears up from the southern tip of Europe – a stark, white geological totem visible from Africa across a sliver of Mediterranean. At its base is a great teardrop-shaped gash with a soaring interior: Gorham's Cave. What dramas played out in this vast cathedral-like space? Whose lives . . . what dynasties . . . lived, loved, worked, birthed, and died within these ancient wave-sculpted walls? The cave was home for tens of thousands of years to our Neanderthal cousins – their last home on Earth.

Let's go back 35,000 years: the continent is locked in a crippling ice age, and those animals that could have left for warmer climes amid plenty of local extinctions. In such harsh times, Gorham's Cave is an idyllic spot. Sea levels are metres lower[1] *and vast hunting plains stretch far out to sea. Scouts higher up on the rock can easily spot prey – or danger, like lions – and signal to those below. In front of the cave's opening are fields of grassy dunes and spring-fed lakes – wetlands that are home to birds and grazing deer. Further around the peninsula are rich clam colonies and mounds of flint. The line of neighbouring caves here has the highest concentration of Neanderthals living anywhere.*

See the community busy with their daily chores: at the shore, children gather driftwood; out on the plains, two women have ambushed a vulture with beautiful black plumage and are carrying it home. Let's follow them into the cave now. The main atrium, with its big hearth, is bustling with activity – families are socializing, preparing meals, working tools, making clothes. A broad-framed man in his twenties, cloaked in tanned skins, is using a stone blade to sharpen the end of a straight poplar branch. Wood shavings curl off his spear *and he kicks them to the edge of the fire. By his side, a stocky red-haired woman is tapping open clams and skewering them with a sharpened bone – her sick aunt will be given this soft food first; they have already buried her child.*

While the food is being cooked, an older man – perhaps he is a shaman – is fashioning a beautiful black feather cape and headdress from the vulture he's been given. These are people with rich interior lives, with time to think and create art. Deep inside the cave, past the little sleeping chambers with their individual protective fires, there is a special nook containing a deliberately carved rock engraving: a crosshatch of parallel lines. Its symbolic meaning will be lost in the befuddling layers of time, whereas creations made further north by other Neanderthals will prove easier to interpret: ochre animal paintings, handprints, necklaces of strung eagle talons and little ochre clamshell compacts.

They don't know it, how could they, but these remarkable people, who evolved outside of Africa with advanced culture and survival skills, are among the last of their kind. Within a single lifetime, drought transforms areas of thick hunting forest into unfamiliar grasslands. The few families that survive suffer more stillbirths, more weakening diseases. Perhaps they have already met the slighter human immigrants, who move in bigger caravans, establishing themselves in lands that were for thousands of years successfully occupied by Neanderthals. How vulnerable we are. What chance that it is I who sits here now and not she, the descendant of my long-extinct cousins?

If we are to answer the question 'What does it mean to be human?,' we might first ask what makes our way of living – our culture – different from that of other animals. Humans are exceptional: despite a growing raft of fascinating behaviours, no animal culture is anywhere near as complex or flexible as ours. Most animals rely on innate skills rather than learning from each other, and their culture isn't cumulative – unlike our technologies, the simple tools used by animals do not appear to have improved significantly over the past few million years.

Nevertheless, a variety of animals do exhibit some form of socially transmitted culture. Such species must be smart enough to learn a novel behaviour and social enough to transmit it. The most sophisticated tool users are our closest living relatives: chimpanzees – our last common ancestor lived 6 million years ago. Primatologists have identified 39 different traditions in chimpanzees across Africa (most populations use around 20), the most complex of which is nut-cracking.

For culture to become cumulative – that is, build on itself in a ratchet-like way with modifications that are selectively adopted and accumulate over time – the demands are far greater. A chimp can crack a nut by bashing it with a stone. Another chimp can learn this culture and it doesn't matter what sort of stone is used or how he bashes it, eventually the nut will probably crack. Developing nut-cracking further to make it more efficient would involve selecting a particular type or shape of stone, or perhaps even shaping the stone. In other words, it would mean adding steps, each of which has to be accurately remembered, in the right order, and demonstrated to another chimp, who would need to learn the steps and their order and also transmit them. Over time, modifications to the method can be made and new steps added until, eventually, the modern nutcracker evolves. As with genetic evolution, culture can only evolve with sufficiently accurate copying, which allows successful modifications – such as stone choice – to be maintained until they can be improved upon. Chimps are unable to do this, whereas we excel at it.

So when did this transition occur, the evolution of an animal with an extraordinary form of evolving culture?

Hard, isn't it, to look at a photograph of yourself as a child and reconcile that image with the adult in the mirror? There you are, the exact same person but for the passage of time and the experience of brain and body.

Looking back through time at those who lived thousands of generations ago requires greater effort in imagination and empathy. And yet those people were not so very different. They too were motivated, by the need for food and a safe home, to seek companionship and to come up with solutions to life's challenges whether social or technological. And they succeeded – some fleetingly; some, like *Homo erectus*, for more than a million years. We glimpse these long-gone cousins rarely but tangibly, finding a thighbone that once supported a purposeful run, or a skull that housed a thoughtful mind. More poignant than their bodies are the remnants of their humanity: tools worked by human hands or the marks they left on a wall, enduring testimony of the impulse to decorate.

Mostly, though, the millions of people that have lived before us have left no trace. They made clothes and tools from flesh and fibre, which have since rotted. Their bodies have been consumed and recycled back into the environment that bore them. We carry echoes of them in our DNA, in certain traits, in our human interactions, and of course we wonder about them, those pioneers of a different way of being, our cultural forebears.

From these clues, a raft of experts – among them paleontologists, anthropologists, geologists, climatologists – is trying to piece together a credible scene from a time when dozens of different human species lived on Earth. There is a famous drawing from 1965, the 'March of Progress' by Rudolph Zallinger, that illustrates human evolution as a parade of different hominids,* beginning with a primate ancestor and leading up to modern humans. It is usually interpreted as a linear progression in which each character is the direct descendant of the ancestor on his left, and pleasingly shows us out in front, winning the evolutionary race to be us. It is, as recent paleontological and genetic findings show, a cartoon whose only bearing on reality is the relatively recent arrival of modern humans. For a start, many of the different characters on the March were species that coexisted and probably interbred. Sex between different types of hominins resulting in genetic hybrids seems to have been commonplace, we are now discovering. Somewhere along this evolutionary transition, a special kind of culture arose, and tracing its emergence means casting back through our shared past for clues.

The earliest candidate is our distinctly modern, ancient human ancestor, *Homo erectus,* who emerged around 1.8 million years ago. By this time, hominin brain size had doubled from 600 to 1,300 cubic centimetres,[2] and these smart, prosocial people were able to remember multi-step processes. Their tools were increasingly sophisticated,

* Hominid refers to humans and apes (living and extinct), whereas 'hominin' refers to modern and ancestral humans (those of the *Homo* genus, which first emerged around 2 million years ago).

unlike the simple tools made by earlier hominids, dating back 3 million years, which could be fashioned by an individual without input from anyone else. *H. erectus* was a remarkably successful fire-making, tool-using, sociable hunter who conquered continents ranging from Africa to Asia and the edges of Europe. They may well have had language and even made simple ocean-going crafts to travel to islands. Genetically, *H. erectus* was very diverse. Different populations spread geographically, intermingling and interbreeding with other related hominins over hundreds of thousands of years. Then, 1.2 million years ago, perhaps owing to climate change, *H. erectus* nearly went extinct, reducing worldwide to a population of just 18,500 breeding individuals.[3] For more than a million years, our ancestors were more endangered than chimps and gorillas are today, and it may be that this population bottleneck, which reduced diversity among hominins, propelled the evolution of our own species.

We don't know how many species of humans there have been, or how many different 'races'* of people, but the evidence suggests that around 500,000 years ago, Africans known as *Homo heidelbergensis* began to take advantage of fluctuating climate changes that regularly greened the continent, and spread into Europe and beyond. But by 300,000 years ago, migration into Europe had stopped, perhaps because a severe ice age had created an impenetrable desert across the Sahara, sealing off the Africans from the other tribes. This separation enabled genetic differences between the populations to evolve, eventually resulting in different races. It is from around this time that the very first evidence[4] for anatomically modern humans – *Homo sapiens* – appears in Africa, where they would develop their cultures and intermingle and breed with other (now extinct) African races, such as the recently discovered *Homo naledi*. Those hominin populations that had left Africa adapted to the cooler European north,

* I describe the different cousin species of human, such as *H. sapiens, Neanderthals, Denisovans*, as different races, because they were genetically similar enough to have interbred with each other successfully, producing fertile offspring. While individual hominin groups may have lacked diversity – they appear to have been quite inbred – their collective diversity was great. For most of our history *sapiens* have existed among other races. Today, there is only one genetically distinct race: ours.

eventually emerging as Neanderthals, Denisovans and others whom we can now only glimpse with genetics.

By the time the first few families of modern humans made it out of Africa,[5] around 80,000 years ago, Neanderthals were thriving from Siberia to southern Spain. Today we find their ghosts living on in our genes – for it seems that wherever we encountered other humans, we bred with them.[6] Everyone alive today of European descent – including me – has some Neanderthal DNA in their genetic makeup, and across the population as much as 20 per cent of the Neanderthal genome is still being passed on, presumably because it has helped us survive in Europe.* Other archaic human races have also left a genetic legacy in modern populations. Indigenous Australians carry genes from Denisovans, a race about whom we know very little, while other, yet-to-be-identified archaic races have influenced the genes of other human populations across the world, including as recently as 20,000 years ago in Africa.[7] Perhaps it is our lascivious nature, which enabled us to collect so many usefully adapted genes from the various hominins we encountered, that helped our ancestors succeed as they spread across the world's environments.

Imagine that time in our history, where people could encounter those of a truly different race – other types of human trying the same cultural experiment. How fragile we all were. What a risk our evolution took when it put all of our survival eggs in that one basket of culture, pitting us against fearsome beasts and cruel climates. We were physically so unprepared for hostile conditions that for most of human history, our survival has been touch and go. Just 74,000 years ago, for instance, a supervolcanic eruption at Toba in Indonesia nearly wiped us all out, and our ancestors' population shrank to a few thousand. Today, although there are several species of ape, only one human species has survived.

* Many of the genes we have inherited from Neanderthals are associated with keratin, the protein in skin and hair. These visible variants may have been sexually appealing to our ancestors (Neanderthals were redheads), or perhaps their genes for tougher skin offered some advantage to the African migrants in the colder, darker European environment. Some Neanderthal genes are now problematic – a gene that may once have helped people to cope with food scarcity now leaves Europeans more prone to diseases like type 2 diabetes.