## Lesson Three
# Evolution

*When we open up to such questions, we open ourselves up to our higher nature. It was asking questions, making connections and trying new things that brought us down from the trees, and took us to the moon.*

## WHO ARE WE?

The mountainous interior of New Guinea offers some of the most treacherous hiking challenges in the world. It is as rough and steep as any other mountain range, but then it is blanketed with a thick, wet rainforest teeming with painful fire ants, sharp stones, and slick mud. My colleague Dan Jorgensen, who did fieldwork just a few valleys away, calls it "vertical rainforest."

In preparation for this, I bought the best boots I could afford – stiff and strong, with mean-looking teeth promising plenty of traction. But they were no match for these mountains. My friends skittered up and down mountains with ease in their bare feet while I clobbered and hobbled along. Every step of mine seemed so heavy and clumsy compared to the graceful and light dance they did as they bounced from tone to stone. We all spent a lot of time on the ground – me crawling on all fours gazing down in terror over the mountain ledges that would surely end my life, them sitting casually up-mountain taking in the good view and enjoying a smoke.

Going down was much worse than going up. I usually took a "sit and slide" approach, seeing no plausible way to stay on two feet and get down safely. Meanwhile they bounded down the same precipice with ease, usually carrying heavy bags full of garden produce, firewood, or even babies.

One day about eight months into my time there, my wife and I were gathering bamboo for a new chicken pen. Fresh bamboo is very heavy, and the 14-foot bundles we put together were especially unwieldy. Our shoulders shrieked with pain as we lumbered along the slick trail home. After struggling for some time, an eight-year-old girl who could not have weighed more than 60 pounds swooped alongside my wife, swung her load of bamboo onto her back, and walked off as quickly as she had arrived, leaving us trailing far behind. Though my wife felt a little ashamed that she had been rescued by an eight-year-old, she was happy to be rid of the load, and walked on toward home as I continued to struggle, heaving the load 30 feet, then 20 feet, then just 10 feet at a time, then stopping to rest and rub my aching shoulder, letting the tall and imposing load stand beside me. I didn't dare let it fall, for I knew I would never be able to stand it up again.

Before long an old woman caught up, carrying a bag full of sweet potatoes on her head. Watching me struggle with the load, she offered to help. She appeared frail and weighed no more than 100 pounds. I was sure she would simply collapse under the weight, so I refused. But she was insistent. She wedged her shoulder into the standing bundle, found the balance point, let the weight sway onto her shoulder, and skittered off toward the house with that quick and light New Guinea step I had come to admire. I had to walk-run-walk like a child with his parents just trying to keep up, but she scurried further and further ahead as I struggled with the uneven terrain. By the time I arrived home, she had already dropped off the bamboo and was on her way.

My wife stood on the veranda, laughing. "Haha!" she teased, "I was feeling really bad until I saw you trailing behind that old woman carrying your bundle!" We marveled at the display of strength we had just seen. Here were two very strong, fit, young Americans shown up by a small child and a frail old grandmother.

I had always seen myself as a fit guy with great balance and athleticism, but the things that ordinary New Guineans of all ages could do simply astonished me. They crossed raging rivers of certain death on small wet logs without breaking stride. They would come to what I would consider a cliff, the end of the trail, and bound straight down it without hesitation or comment. They climbed trees I would consider unclimbable, and then walk out on a thin branch 30 feet above the ground as if it were the earth itself, and slash branches above them with a machete while not holding on to anything to secure themselves.

Yet there were some things we could do that they could not. A 20-foot steel pole, part of an old radio tower, had been abandoned in the village for some 30 years from an unfinished colonial project. It probably weighed about 150 pounds. My wife and I could both dead-lift it. Nobody else in the village, even the strongest looking men, could do so. So at least we had that on them. We could do the relatively useless task of dead-lifting a uniform, unnatural, perfectly balanced steel bar off of the ground, but we couldn't carry a bundle of heavy, unwieldy, slippery, and bumpy bamboo. We could not navigate their paths and makeshift "bridges" without sometimes reverting to crawling. We could not harvest our own tree fruit. We could not carry large bundles of firewood on our heads. In short, we might be "strong" and "fit" by American standards, but we simply could not do any of the basic tasks required for survival in New Guinea.

Watching such feats was a continuous reminder of another question that had brought me there: Who are we as human beings? What are we capable of? On a deeper level, the question is not just about physical abilities, but also about our intellectual abilities as well as our moral capacities and inclinations. What is our nature? When my friends stopped and cried with me on the mountain, were they tapping into some deep aspect of our human nature, or was that an aspect of their culture? Are we inherently good or bad? Are empathy and compassion natural inclinations, or are we more prone to be jealous and judgmental?

To explore these questions, we need to expand our view beyond humans today and look to our evolutionary past. We have to look at our closest animal relatives, as well as the fossil record, to explore what we can learn about our ancestors.

Evolution has been a touchy and controversial topic since Charles Darwin first introduced the idea in 1859. Darwin himself waited 23 years before publishing *The Origin of Species,* because he knew it would contradict the account of creation in Genesis and set off a broad public debate. Around the same time, Charles Lyell published evidence that the earth was much older than the Biblical 6,000-year-old timeline. Ever since, those of us who grow up in cultures with a Biblical tradition have had to wrestle with difficult questions about how to square scientific knowledge with our religious faith.

While evolution is still strongly debated in public, it has long been firmly accepted in science. While critics like to point out that it is "just a theory," the phrase misunderstands the definition of scientific theory. A scientific theory is not an unproven hypothesis. The National Academy of Sciences defines a theory as "a well-substantiated explanation of some aspect of the natural world." Theories are not tentative guesses or even well-reasoned hypotheses. They take in a wide range of well-established facts and laws and make sense of them. "Theories," the Academy notes, "are the end points of science."

So evolution, like any scientific theory, is not something to be simply believed or disbelieved. It is to be understood and continuously reassessed based on the evidence. As Stephen Jay Gould points out, evolution is not only a theory, it is also an established scientific fact due to the mountains of data and observations supporting it. Nothing is absolutely certain in science, so "scientific fact" does not mean "absolute certainty." Rather, a scientific fact is something that is "confirmed to such a degree that it would be perverse to withhold provisional assent."

Does this mean that God does not exist and that the Bible is wrong? This is a difficult question that each of us has to answer for ourselves. Most Americans who become college-educated end up accepting evolution (73%) and many of them see God as guiding the process or having planned the process out from the beginning of time (41%). Many professional evolutionary scientists hold this view as well, and it affords them the great joy of exploring the vastness of our world and its history. As my friend and colleague Keith Miller, who is both an evangelical Christian and an evolutionary scientist, wrote in a now-famous article on the theological implications of evolution, "Our continually developing scientific understanding of cosmic history should produce great awe at God's incalculable power and wisdom ... He instructed Job to contemplate the created universe. When we contemplate the universe today should we not, even more than Job, be overwhelmed by God's greatness?"

So one reason to study evolution is to simply stand in awe of the unfolding cosmos that has ultimately led to this moment right now. But there are other, more practical reasons as well. Studying evolution helps us understand who we are at the biological level. It helps explain how and why we get stressed, why we are prone to getting fat, and why we are prone to fall into bad habits. Most of us will die of a disease that is caused by a mismatch between the environments that we evolved to survive in, and those that we live in today. Understanding our evolutionary past can help you stay alive. It can also explain why we are prone to fall in love, feel jealous, or rage with hate or fear. Our biology is always a part of our lives. We tend to deny this fact, but the more we acknowledge it and learn about it, the better we will be able to handle the ups and downs of everyday life, stay healthy, and perhaps even do some things that we never thought possible.

As a small-town kid from Nebraska, I also had to wrestle with these questions. It was a constant source of discussion and debate in my college dorm, often taking us deep into the early hours of the morning. While my own conclusions are irrelevant to your own, I simply want to note that I am grateful that my conclusions allowed me to open up to the wealth of research and information emerging out of evolutionary science today, as they have greatly enriched my life. They have helped me understand who we are, our human potential, and most importantly, helped me regain much of the human potential I had lost through years of unhealthy habits. While this chapter cannot possibly tell the entirety of the human story or pass on all of the wisdom to be gathered from an understanding of human evolution, I hope that it can serve as an invitation for you to explore more.

## 20 MILLION YEARS AGO:<br>THE MONKEY ALLIANCE

Step into the Tai Forest of Africa and you will hear a wild cacophony of calls, sounds, and melodies that would have been familiar to our ancient ancestors. Birds singing, monkeys hooting, bugs chirping, frogs croaking, and a multitude of other sounds fill the air. Listen closely enough, and you can start to tune into the conversation.

Klaus Zuberbuhler has spent years studying the calls of the primates in this forest. In one study, he started by playing leopard sounds and then listened for the response. Diana monkeys sitting in the forest canopy always responded with the same recognizable alarm call. He played the shrieks of an eagle and heard what he thought was the same call. But back in his lab he created a spectrogram of the calls and discovered that they were actually different calls. The Diana monkeys were distinguishing threats from above, like eagles, from threats from below, like leopards, with subtle variations in pitch. They were singing, and using their songs for survival.

One day, Klaus was walking through this forest when, suddenly, his ability to tune into this conversation became a matter of life or death. Diana monkeys were sounding an alarm from high in the trees above him. A leopard was in the area. As he moved through the forest, the calls moved closer and seem to follow his every move. The leopard was stalking him! He kept his ears tuned into the Diana monkeys overhead and quickened his pace, walking with anxious deliberation toward the safety of his camp. He dared not run.

Inside Klaus's body, an ancient stress response kicked in. He was filled with a rush of adrenaline. Without making any conscious decisions, he cashed in on the fat he had stored up for just such an occasion. It was transformed into glycogen, which raced through his bloodstream, powered by his racing heart. His awareness heightened. Meanwhile, all of his body's long-term projects ceased. The body shut down repair, growth, and reproduction. His body was fully primed and in the moment. No time for long-term goals now.

This basic biological stress response is one that he shares with the monkeys, as well as the leopard and all other creatures of the animal kingdom. Everyone in that life or death drama is completely in the moment as their fight or flight response kicks in.

The monkeys above swarmed the leopard. They did not run away. Their calls could be heard across monkey species, allowing monkeys of different types to form a sort of monkey alliance, constantly calling out and staring down at the leopard from multiple angles to let the leopard know they had him in their sights. Leopards like to attack by ambush. As the monkeys swarmed overhead, the leopard knew its cover was blown, and it gave up the hunt. Klaus made it safely back to camp, saved by his distant brothers and sisters, exhilarated by the experience of hearing, and actually understanding, the language of these distant relatives, separated by over 20 million years of evolution. For a moment, he remembered that he too was part of that great monkey alliance.

Though the Diana monkeys of today are not the Diana monkeys of 20 million years ago, fossil evidence shows that creatures that looked very much like Diana monkeys existed 20 million years ago, and are likely the common ancestor of ourselves *and* those monkeys who were sounding the alarm from those trees.

How did we split and become separate species? In order for new species to occur, there has to be some form of reproductive isolation. This usually happens as populations become geographically isolated from one another and end up occupying different environments. Slowly, generation after generation, some genes are passed on while others are not, and given the different environments, the two populations eventually become so different they can no longer reproduce with one another. They are now permanently isolated reproductively, and have become separate species.

The past 25 million years in East Africa have been an especially prime period for speciation among primates. Climate changes, along with high levels of volcanic activity, dramatically reshaped the Earth. creating numerous environmental niches within a fairly small geographic region. Populations that found themselves in lush jungle rainforests adapted very differently from those who found themselves in more sparsely vegetated woodlands or open savannahs. By 13 million years ago, our ancestors split from orangutans, and by eight million years ago, from gorillas. We split from chimpanzees and bonobos (a.k.a. pygmy chimpanzees) by about six million years ago.

## WHY WE SING

The ability to sing is shared widely among birds and mammals. And while our closest relatives are quite good at communicating through singing, the most complex use of a "singing" language among mammals might not belong to them, but to prairie dogs. While they may not share much DNA with us, they do share a similar challenge. Much like the early hominids who first came down from the trees, prairie dogs are easily spotted in the wide-open grasslands by a vast range of predators. Singing is a survival strategy.

Prairie dogs have created different calls for coyotes, badgers, and hawks, all of which require different defense responses. In experimental situations, biologist Con Slobodchikoff has demonstrated that prairie dogs can sing different chirps to indicate the shape, color, speed, size, and mode of travel of a potential incoming threat.

While not as sophisticated as the songs of prairie dogs, most birds and mammals have at least some rudimentary singing abilities that allow them to communicate. The simplest singing systems in the animal kingdom involve two sounds, a low-pitched growl often used as a threat, and a higher pitched melody used to indicate friendliness, submission, or vulnerability. A dog growls deeply as a threat, and yelps or squeals meekly when threatened. A dog might also use a high-pitched whimper as he cuddles into a human, a clear request for a pet or cuddle. Weaver birds, crows, guinea pigs, rats, Tasmanian devils, elephants, and monkeys use low and high tones in similar fashion. "Simply stated," noted Eugene Morton of the National Zoo after a review of over 70 species, "birds and mammals use harsh, relatively low-frequency sounds when hostile and higher-frequency, more pure tonelike sounds when frightened, appeasing, or approaching in a friendly manner." Linguist John Ohala notes that these pitch variations are part of a universal "frequency code" that extends across species, in which low, deep, full sounds indicate dominance and aggression, while high thin sounds indicate harmlessness, submission, or a plea for connection. You tap into it every time you lower your voice to admonish your dog or raise your voice to ask for a snuggle.

There is significant evidence that our ancestors were using a much more complex singing system to connect and collaborate. Thousands of miles from the cacophony of the Tai forest or the chirping of prairie dogs on the North American Plains, Ann Fernald was sitting in an obstetrics unit in Germany listening to some interesting songs as well, those coming from the mothers of newborn humans. The hospital attracted mothers from all over the world;

many languages, and many cultures. But when they spoke to their babies it was as if they were all tapping into that same evolutionary heritage that Klaus was trying to uncover in the Tai Forest. They raised their pitch, exaggerated their emotional tone, slowed down, shortened their sentences, and often repeated themselves. They were using that ancient singing language, and though they were coming from many different cultures and speaking many different languages, Ann knew the tunes. It was there that she discovered four universal songs of baby-talk:

1. The approval song with its rising and then falling pitch (GOOD girl!);
2. The warning and prohibition song with its short, sharp staccato (No! Stop!);
3. The lingering and smooth, low frequency comfort song ("oh …. poor little baby …" ); and
4. The song she calls "The Attention Bid," a high, rising melody, often used for asking questions and calling attention to objects ("Where's the BALL?").

To explore just how universal these songs might be, Greg Bryant and Clark Barrett of UCLA recorded English-speaking mothers talking to their babies and went into the Amazon rainforest to see if the Shuar, a group of remote hunter- horticulturalists, also knew the tunes. They did.

The universality of the songs indicates that they are very old. Our first ancestors probably knew similar tunes. We hear similar tunes among our closest relatives, gorillas and chimpanzees. When lowland gorillas hear strange sounds or spot obscured observers, they sound a mild alert that Dian Fossey called the "question bark." The bark, with a rising intonation that falls at the end, was described by Fossey as sounding like "Who are you?"

Jane Goodall describes "inquiring pant-hoots" that rise in pitch, like human questions used by chimpanzees. After the pant-hoot a chimp will listen quietly for a response from another chimp, and in getting one, learns the whereabouts and identities of other chimps nearby. Long before full human languages developed 100,000 years ago, we were probably sending messages through simple songs like these. And the songs we sang said a great deal about who we were. We asked questions. We showed compassion for one another. We helped each other avoid dangers, and we offered each other encouragement. Taken together, they represent four key capacities: teaching, learning, cooperation and compassion. All would have been great assets as we walked off into the dangerous open grasslands.

## SIX MILLION YEARS AGO: WE WALKED

As you think about just how vulnerable Klaus was as he walked through a forest full of dangerous predators like that leopard, consider just how astounding it is that we ever evolved to come down from the trees at all. Yet we did. About six or seven million years ago, we start to see the tell-tale signs of bipedalism (walking on two legs) emerging. Hominid bones found from that time show a pelvis starting to tilt sideways, an S-shaped spine, and a stiffened foot with upward curving toes, all of which would help us walk without waddling but reduced our capacities to climb trees.

But why? Why would we come down from the safety of the trees where fruit was plentiful and predators were not? How could we even begin to escape or compete with the big cats who could run up to 60 mph and had powerful jaws and ferocious fangs and claws? We had no weapons – natural or man-made – and weren't even as tall or large as we are today. We were just 4 feet tall and weighed about 110 pounds, the size of a husky third-grader.

*How did we do it? Why did we do it?*

We probably had no choice. The Earth was cooling and forests were shrinking, especially in East Africa, where our ancestors lived. Dense rain forests were giving way to woodlands and open grasslands. Fruit dwindled along with the dwindling forests. What fruit was left was being eaten up by monkeys who had developed abilities to eat unripened fruit, picking over the trees before we could even get to them.

As fruit sources dwindled, one strategy for survival was to simply get better at obtaining fruit. The ancestors of chimpanzees did this, using their remarkable agility to swing through trees in order to get at hard-to-reach fruit, and to occasionally pick off unsuspecting prey. Another strategy was to adapt to a fruitless diet where there was less competition. The ancestors of gorillas did this, moving to a diet of leaves and growing to large sizes that slowed their metabolism, requiring fewer calories.

But while these strategies could work in dense forested environments, they would not work in lightly forested woodlands and grasslands where our ancestors lived. Leaves and fruit were not as plentiful. Instead of focusing on just one food source, we developed abilities eat many kinds of food, including meat, and to move more efficiently on land so that we could cover more ground and thereby gather more food. We also retained some of our climbing abilities so could exploit a wide range of foods in the trees, on the ground, and under the ground (roots and tubers).

In other words, we didn't give up on tree-climbing and become bipedal overnight. One of the best-preserved skeletons from four million years ago, nicknamed 'Ardi,' shows that our ancestors at this time retained grasping toes and other features that would still allow them to climb remarkably well by modern human standards, but they were also not as efficient at walking as we are.

Many people assume we became bipedal so we could use tools, but we wouldn't start using tools for at least a million years after we first started walking. The original advantage of walking on two legs was efficiency. While chimps only walk about 1.5 miles a day, a modern human can walk about six miles a day using the same amount of energy. Our earliest ancestors were probably not as efficient at walking as we are today, but even a slight increase in efficiency would have allowed them to travel and gather foods over a wider range and still maintain the calorie balance they needed to survive and reproduce.

Over time, the more efficient walkers were more likely to reproduce, and so generation after generation we became more and more adapted to walking, able to cover more and more territory.

While standing up made us more visible to predators, it also allowed us to spot them and take away the element of surprise, just as those Diana monkeys did for Klaus. This is where our ancient ability to sing would be so important.

Singing, collaborating, and walking on two legs would set off a cascade of changes that would make us who we are today. With our hands free, we could carry food back to our young and elderly, broadening our abilities to share, and eventually develop more sophisticated tools and technologies. Each technology not only improved our abilities to acquire food, but would also change how we worked and lived together. The hominid brain grew as we were able to obtain more calories to fuel its growth, and it needed to grow in order to deal with the increasing demands of cooperation and navigating increasingly complex social relationships.

By 2.5 million years ago, we were fully committed to life on the land. Our capacities to climb and live in the trees had dwindled along with the size of our arms, fingers, and toes. We could no longer grab a branch with our feet or swing effortlessly from tree to tree. But our legs were now long, straight, and efficient. We were no longer just walking. We were running, but before we could run efficiently, we would have to develop yet another key adaptation.

## 2.5 MILLION YEARS AGO: WE GOT FAT AND SWEATY

Our growing brains required a constant source of energy, which would have been difficult to maintain if it also required a constant source of food in sometimes unpredictable and sparse environments. Fortunately, we got fat. Fat is rich in energy, storing nine calories in each gram (vs. just 4 calories per gram of carbohydrate or protein). When food was scarce, we could call upon the fat reserves we stored on our bodies to sustain us. Those who could survive through the leanest of times would be those who would reproduce to create the next generation. And generation after generation, we got fatter.

The average monkey is born with about 3 percent body fat, while we humans are born with fifteen percent. A healthy human child will blossom to an energy-potent 25 percent body fat before settling back down into the teens in adulthood. A typical female hunter-gatherer has a body fat of about 15 percent, while a male weighs in at about 10 percent – thin by American standards, yet still much fatter than chimpanzees.

Getting fat was essential to our survival, and to this day we maintain a remarkable ability to pack it on when the feeding is good. Our tastes evolved to help us gorge on high calorie foods whenever they were available, so we have natural cravings for fatty or sweet foods, both of which are especially high in calories.

As we gained the capacity to store fat, we also lost our fur and covered our skin with sweat glands, allowing us to stay cool even in the heat of the African equatorial sun. While other animals have to rely on circulating air through their bodies as quickly as possible by panting, we can simply let the air move around us as we sweat, making us the most efficient air-cooled bio-engine on the planet.

## TWO MILLION YEARS AGO: WE RAN.

By two million years ago, our ancestors started to look very different from chimpanzees. Our bodies became more adapted for life on the ground, not in the trees. Our legs grew longer and thinner near the ends, giving us a longer and lighter step. Our toes got shorter, our butts got bigger, and our arms grew shorter, allowing us to be more stable and efficient while running. Our heads became more separated from the shoulders, creating the need for the nuchal ligament, used to stabilize the head. Our joint surfaces expanded to reduce the shock of each footfall. The plantar arch and Achilles tendon gave us more elastic energy. Our legs became biological springs. The springy arch of our foot increases our running efficiency by 17%.

The combination of running adaptations makes running only 30-50 percent less efficient than walking. By 2004, the research team of Daniel Lieberman, Dennis Bramble, and David Carrier had identified 26 adaptations in the human body that were necessary for running that are not required for walking. As Chris MacDougal famously summarized, we were "Born to Run."

Despite all these remarkable adaptations for running, we're not very fast compared to other animals. The fastest land animals have four legs, allowing them to thrust themselves to speeds well over 40 mph and sometimes, as in the case of the cheetah, to over 60 mph. The fastest humans can only run about 27 mph.

But despite being slow, we had several key advantages. Our ability to sweat would allow us to move around in the heat of the day, while the most dangerous predators and scavengers rested in the shade. Though we did not yet have spear-tipped projectiles for hunting, we would have been able to gather plant foods and scavenge for meat across great distances in the heat of the day. Walking on two legs also freed our hands and allowed us to enter potentially dangerous situations to find or scavenge whatever we could, grab it, and then quickly carry it back to safer ground.

These abilities might also help explain a peculiar mystery in the archaeological record. By 1.9 million years ago, there is evidence that we were successfully hunting wild game such as kudu and wildebeest. But stone spear heads do not appear until 300,000 years ago, and it is nearly impossible to kill a large animal with a wooden tipped spear unless you're very close to the animal, which is impossible if the animal is not in some kind of distress. So if we were successfully hunting large game 1.9 million years ago, long before the invention of adequate weapons – how did we do it?

It turned out that being fat, sweaty, and able to cooperate is a deadly weapon. Lieberman's research team found that our running abilities, combined with our ability to burn fat reserves and cool ourselves with sweat, allowed us to jog faster and farther than most quadrupeds can sustain, especially in the hot midday sun. All we had to do was flush an animal like a kudu or wildebeest out of the herd and scare it into a gallop. It would need to pant to cool down, but it cannot pant while running. If we could keep it on the run over a long period of time, it would collapse of heat exhaustion. We could literally run our prey to death. They called it "persistence hunting."

Lieberman and his team had the biological markers and the mathematical evidence to support their claim. But while there were several stories of persistence hunting in cultures around the world, there had not been a confirmed observation that such a feat was possible.

The evidence they needed would come from a college dropout driven by a very big question. In the early 1980s, Louis Liebenberg was taking a philosophy of science class at the University of Cape Town when he started asking the big question of how humans ever came to contemplate big questions in the first place. He had a hunch that the first complicated thinking might have come from the challenge of tracking wild game, which would have forced early humans to use a great deal of imagination and reasoning to decode the path and whereabouts of an animal based on a few tracks in the earth. Like all great questions, the question took him farther than he ever thought possible, and before long he was trekking out into the desert to find one of the last bands of the Kalahari Bushmen still living a more or less traditional way of life. After finally finding them, he settled in and lived with them for four years.

One day they invited him on a hunt. They walked for nearly twenty miles before finally coming upon a herd of kudu. They started running. The herd scattered, allowing them to separate one from the herd. Each time the kudu ran under a tree to rest. they would flush it out into the sun while corralling it away from the herd, keeping it isolated. After a few hours of being chased, the kudu started to falter, and then fell to the ground. The Bushmen had their prey, and Louis had unequivocal evidence that persistence hunting is not only possible, but still happening today.

This means that for the past two million years, our ancestors have been routinely walking and running 20 miles to chase down wild animals. The traits that allowed them to do this are the same traits we have today. Yet today, few of us can run even a few miles at a time, let alone 20.

The Raramuri of the Copper Canyons of Mexico also engage in persistence hunting, running deer and wild turkeys to death. By frightening large turkeys into a series of take-offs, they eventually tire and lack the strength to get away from the hunters.

The Raramuri give us an enticing glimpse into the full potential of our endurance running bodies. Reports of their astounding running abilities reached bestselling author and sports journalist Chris MacDougal, who eventually found his way to their homeland to see them in action and write the bestselling book *Born to Run*. He reports that the Raramuri (also known as the Tarahumara) regularly run over 100 miles at a single go.

Most remarkably, Raramuri of all ages can run like this. In fact, it is often the elders – those over 50 years old – who are the fastest. In 1992, a few Raramuri came to the U.S. to race in the Leadville 100, an ultra-marathon of 100 miles over the Colorado Rockies. They wanted to bring their best, so they brought Victoriano Churro, a 55-year-old Raramuri grandfather.

Historian Francisco Almada reports that a Raramuri man once ran 435 miles without stopping, and reports of others running over 300 miles are not uncommon.

What allows the Raramuri to run so far, over such tough terrain, and for so long (well into old age), is that they run with that same gentle skitter step I had come to admire among my friends in New Guinea. Like our ancestors, they are running barefoot or with very thin homemade sandals. This forces them to stay light on their feet, taking short quick strides and landing on the ball of their forefoot in order to absorb the impact, rather than striding out and striking their heel, the style preferred by most runners shod in thick-soled running shoes.

Noting the low injury rate among barefoot runners around the world, Dan Lieberman did a study of the Harvard track team, comparing athletes who were forefoot strikers (barefoot style) versus those who were heel strikers. The injury rate for heel strikers was 2.6 times that of forefoot strikers.

But perhaps the most striking feature of the running style that Chris MacDougal and others found among the Raramuri, and that I witnessed among my friends in New Guinea, is the pure joy they take in running. It is not a penance for indulging in too much food. It is not "exercise" or "working out." It is fun. "Such a sense of joy!" legendary track coach Joe Vigil exclaimed as he watched the Raramuri laugh as they scrambled up a steep mountainside 50 miles into the Leadville 100.

When Ken Choubler, the race's founder, saw the Raramuri running after over 50 miles on his grueling mountain course, he would tell MacDougal that they looked normal—"freakishly ... normal." They didn't have their heads down, face grimacing with pain, just trying to tough it out. They were enjoying themselves. "That old guy?" MacDougal writes, "Victoriano? Totally cool. Like he just woke up from a nap, scratched his belly, and decided to show the kids how the big boys play the game."

Victoriano, age 55, won the race that day, edging out a younger Raramuri runner for the win. The top non-Raramuri competitor was six miles back.

## MODERN HUMANS AND THE CREATIVE EXPLOSION

Taken all together, the evidence suggests that starting approximately two million years ago, we were still relying on the gathering of fruits, nuts, and tubers over a wide area as our primary means of subsistence. We scavenged and hunted when opportunities arose, and we were starting to develop some basic stone tools to cut and process our food.

A positive feedback loop started to emerge. The better we got at obtaining food, the more calories we had to grow our brains. As our brains grew, we got better at obtaining food. By about 500,000 years ago, we had enough intelligence to invent a stone-tipped spear capable of penetrating thick animal hides at great distances, and our upright running bodies were adapted to throw them with a force and accuracy unmatched among all other animals. A chimpanzee can be trained to throw, but they can only throw at about 20 mph. A human can wind their upright body up like a rubber band and let the rotational force of their full body, along with the rotation of their shoulder, combined to generate speeds of up to 9,000 degrees of rotation per second. Even a mediocre human athlete can throw up to 70 mph with remarkable accuracy. Most impressively, we could not only throw accurately enough to hit a rabbit, we could hit a *moving* rabbit. Our ability to hit a moving rabbit requires yet another key human skill: imagination.

Neil Roach, anthropologist at George Washington University, told MacDougal that "this ability to produce powerful throws is crucial to the intensification of hunting." Once we could obtain a steadier high-quality source of meat, "this dietary change led to seismic shifts in our ancestors' biology, allowing them to grow larger bodies, larger brains, and to have more children."

The positive feedback loop would continue as we domesticated fire approximately 400,000 years ago, allowing us to obtain more and more high-quality calories from our foods by cooking them. We could also stay warm in colder climates, expanding into new territories, and share stories and information as we sat around the fire well into the night, having artificially extended the day for the first time.

By 200,000 years ago the first modern humans, *Homo sapiens*, had arrived. Genetically, they were us. If you could transport a newborn from 200,000 years ago into the present, they would learn our language, go to school, and fit right in. Every human on the planet today can trace their roots back to these African ancestors, 200,000 years ago. We had dark skin to protect us from harsh ultraviolet rays of the sun. Compared to the animals we evolved from, we were fat and sweaty. But we could run long distances, throw, make tools, use our imaginations, and perhaps most importantly, communicate and collaborate better than any other creatures in the world.

Communication and collaboration allowed us to develop even more sophisticated technologies, including clothing, that would allow us to spread out of Africa and settle all over the world. Our trade networks expanded, allowing innovations to be shared over greater and greater distances. The archaeological record shows an explosion of creativity starting around 50,000 years ago, sometimes called *the Creative Explosion.* A technique for the mass manufacture of thin stone blades was discovered. Tools became more sophisticated and versatile. Atlatls, notched sticks into which we placed the butts of our spears, increased the amount of force we could use to hurl those spears, achieving faster speeds and more power. Nets and fishhooks allowed us to expand our diets to more seafood, while new methods of food preparation such as grinding and boiling allowed us to use and process more and more of the calories available to us. We told stories, painted pictures, made jewelry, and developed a rich, symbolic world that would tie us together into larger, more complex groups.

In short, we invented *culture*. We asked questions, made connections, and tried new things. From that moment forward, the pace of our cultural innovation would far outstrip the human body's ability to adapt to the new environments we created.

## LEARN MORE

- The Story of the Human Body by Daniel Lieberman
- Born to Run by Chris McDougall
- RadioLab Podcast: Wild Talk
- RadioLab Podcast: Musical Language