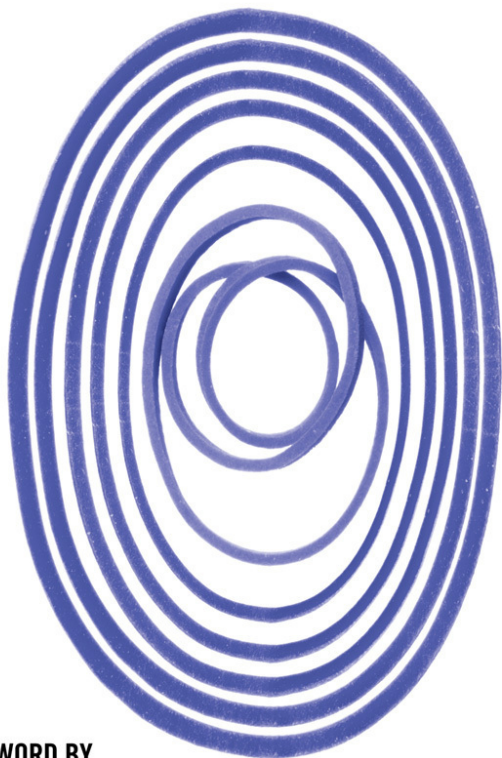


**ENDURE MIND, BODY,
AND THE CURIOUSLY
ELASTIC LIMITS OF
HUMAN PERFORMANCE**
ALEX HUTCHINSON



FOREWORD BY
MALCOLM GLADWELL

Alex Hutchinson

Endure: Mind, Body and the Curiously Elastic Limits of Human Performance

Аннотация

‘This book is AMAZING!’ – MALCOLM GLADWELL ‘If you want to gain insight into the mind of great athletes, adventurers, and peak performers then prepare to be enthralled by Alex Hutchinson’s Endure.’ – BEAR GRYLLS How high or far or fast can humans go? And what about individual potential: what defines a person’s limits? From running a two-hour marathon to summiting Mount Everest, we’re fascinated by the extremes of human endurance, constantly testing both our physical and psychological limits. In Endure Alex Hutchinson, Ph.D., reveals why our individual limits may be determined as much by our head and heart, as by our muscles. He presents an overview of science’s search for understanding human fatigue, from crude experiments with electricity and frogs’ legs to sophisticated brain imaging technology. Going beyond the traditional mechanical view of human limits, he instead argues that a key element in endurance is how the brain responds to distress signals—whether heat, or cold, or muscles screaming with lactic acid—and reveals that we can train to improve brain response. An elite

distance runner himself, Hutchinson takes us to the forefront of the new sports psychology – brain electrode jolts, computer-based training, subliminal messaging – and presents startling new discoveries enhancing the performance of athletes today, showing us how anyone can utilize these tactics to bolster their own performance – and get the most out of their bodies.

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ENDURE

**MIND, BODY AND THE CURIOUSLY ELASTIC
LIMITS OF HUMAN PERFORMANCE**

ALEX HUTCHINSON

FOREWORD BY MALCOLM GLADWELL

Copyright

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Dedication

For my parents, Moira and Roger, whose curiosity, rigor, respect for differing perspectives, and talent for clarity remain the model I strive for in everything I write.

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Foreword

By Malcolm Gladwell

All distance runners have races that, in retrospect, make no sense. I have two. The first came when I was thirteen, in my first year of high school. With no more than a month of training under my belt, I ran a cross-country race in Cambridge, Ontario, against boys two years older than me. One of them was among the best distance runners for his age in the province. I can summon the memories of that race even today, forty years later. I simply attached myself to the leaders at the beginning and never let go, and ran myself to complete exhaustion, finishing a close and utterly inexplicable second. I say *inexplicable* because although I would go on to have a creditable career as a middle-distance runner on the track in high school, that race remains the only truly superb distance race I've ever run. I've underperformed at anything over 1,500 meters for the rest of my running life.

That is: with one exception. Two years ago, at the age of fifty-one, I ran a magical 5K in a small-town race in New Jersey, finishing a full minute faster than any 5K I'd entered since returning to serious running as a Master. On that summer day in New Jersey, I was suddenly my thirteen-year-old self from forty years ago in Cambridge. I dreamt big. I marveled at my running prowess. And then? Back to mediocrity again.

Like the obsessive person—and particularly obsessive *runner*—that I am, I have puzzled endlessly over two those anomalous races. I have running logs from my teenage years, and I've gone back over them, looking for clues. Was there some indication in my earliest training of that kind of performance? Did I do something special? For my latter 5K, of course, I have infinitely more. Months of data from Garmin on every workout leading up to the event, and then still more from the day of the race itself: pace, cadence, splits. On more than one occasion, leading up to a race, I've attempted to replicate the exact preparation I had for my New Jersey PR. I want lightning to strike twice. It hasn't, and I'm beginning to suspect the reason it hasn't is that I don't properly understand what it means to perform a feat of endurance. I think you can see where I'm going with this: I am the perfect audience for Alex Hutchinson's *Endure*.

A few words about Alex Hutchinson. We are both Canadians and both runners, although he is both a better Canadian (he still lives there; I don't) and a *much* better runner than I ever was. He invited me once to a tempo run he does with his friends on Saturday mornings in a cemetery in North Toronto. As I recall, I finished last—or maybe second last, since one of his running crew very sweetly condescended to run at my pace. Alex disappeared from sight after the first bend. As you will discover, as you continue in these pages, Alex writes about the mysteries of endurance as a student of the science, a sports fan, and a keen observer of human performance—but also as a participant. He

has his own anomalous races to explain.

It must be stressed, though, that this is *not* a running book. There are plenty of running books out there, and as a runner I have read many of them. But they are insider's accounts written for other insiders: whether or not a runner should fore-foot or heel-strike, or aim for a cadence of 180 strides per minute, is a question only of significance to runners whose self-involvement extends all the way to the soles of their feet. But one of the (many) pleasures of *Endure* is how convincingly Hutchinson broadens the stakes. In one of my favorite passages, from the chapter on pain, Hutchinson writes of the attempt by Jens Voigt to break cycling's "one-hour" record. Voigt was famously indifferent to pain. But when he climbed off his bike, after breaking the record, Hutchinson tells us he was in agony: "the pain he'd been pushing to the margins of his consciousness came crashing down." That is a cycling story. But in Hutchinson's hands it also becomes a way of asking a much deeper and more consequential question about how our physiology interacts with our psychology. In a wide variety of human activity, achievement is not possible without discomfort. So what is our *relationship* to that pain? How do the signals of protest from our brain interact with the physical will to keep moving? You don't have to be a maniacal cyclist to appreciate that discussion. If anything, that discussion is likely to dissuade you from ever becoming a maniacal cyclist. "Everything was aching," Voigt said. "My neck ached from holding my head low in that aerodynamic position.

My elbows hurt from holding my upper body in that position. My lungs hurt after burning and screaming for oxygen for so long. My heart hurt from the constant pounding. My back was on fire, and then there was my butt! I was really and truly in a world of pain.” Oh man. It was painful just to read that passage.

Does *Endure* solve the puzzle of the anomalous race? In one sense, yes. My problem, I now realize, is that I tried to make sense of those performances using an absurdly simple model of endurance. The time I ran was my output. And so I worked backward and tried to identify the corresponding inputs that must have made it possible. Did I take one day of rest beforehand, or two? How quick was that hill workout the week before? Is there something to be learned from the last set of intervals I did? The data that we gather from our GPS sports watches makes this kind of thinking even more seductive: it encourages us to paint a simple picture of how and why our body moves through the world. After you’ve read *Endure*, I promise you, you’ll never settle for the simple picture again. There are many things Garmin cannot tell you. And luckily, for those many things, we have Alex Hutchinson.

Two Hours May 6, 2017

The broadcast booth at the Autodromo Nazionale Monza, a historic Formula One racetrack nestled in the woodlands of a former royal park northeast of Milan, Italy, is a small concrete island suspended in the air over the roadway. From this rarefied vantage point, I'm trying to offer thoughtful guest commentary to a live-streaming audience of an estimated 13 million people around the world, many of whom have roused themselves out of bed in the middle of the night to watch. But I'm getting antsy.

The race beneath me is hurtling toward a conclusion that almost no one, through months of speculation and spirited debate, had considered possible. Eliud Kipchoge, the reigning Olympic marathon champion, has been circling the racetrack for an hour and forty minutes behind an exquisitely choreographed formation of runners blocking the wind for him—and, remarkably, he's still on pace to run under two hours for 26.2 miles. Given that the world marathon record is 2:02:57, and given that records are usually shaved down in hard-fought seconds, Kipchoge's performance is already straining the limits of my ability to convey surprise and awe. Giant screens in front of me are flashing detailed statistics about Kipchoge's run, but my mind is drifting away from punditry. I want to slip out of

the booth and get back down to the side of the track—to feel the crackling tension in the assembled crowd, to hear the rasp of Kipchoge’s breath as he runs past, and to look into his eyes as he pushes deeper into the unknown.

In 1991, Michael Joyner, an ex-collegiate runner from the University of Arizona who was completing a medical residency at the Mayo Clinic in Minnesota, proposed a provocative thought experiment. The limits of endurance running, according to physiologists, could be quantified with three parameters: aerobic capacity, also known as VO_2max , which is analogous to the size of a car’s engine; running economy, which is an efficiency measure like gas mileage; and lactate threshold, which dictates how much of your engine’s power you can sustain for long periods of time. Researchers had measured these quantities in many elite runners, who tended to have very good values in all three parameters and exceptional values in one or two. What would happen, Joyner wondered, if a single runner happened to have exceptional—but humanly possible—values in all three parameters? His calculations suggested that this runner would be able to complete a marathon in 1:57:58.

The reactions to his paper, which was published in the *Journal of Applied Physiology*, were mostly quizzical. “A lot of people scratched their heads,” Joyner recalls. The world record at the time, after all, was 2:06:50, which the Ethiopian runner Belayneh Densimo had run in 1988. A sub-two-hour marathon was not on anyone’s radar—in fact, when Joyner first presented his ideas in

the mid-1980s, the idea was considered so preposterous that his paper was initially rejected for publication. But the seemingly outrageous time was not a *prediction*, Joyner emphasized—it was a challenge to his fellow scientists. In some ways, his calculation was the apotheosis of a century’s worth of attempts to quantify the outer limits of human endurance. This is how fast a human can run, the equations said. So what explained the chasm between theory and reality? Was it simply a question of waiting for the perfect runner to be born or the perfect race to be run—or was something missing from our understanding of endurance?

Time passed. In 1999, the Moroccan runner Khalid Khannouchi became the first person to dip below 2:06. Four years later, Paul Tergat of Kenya breached 2:05; five years after that Haile Gebrselassie of Ethiopia broke 2:04. By 2011, when Joyner and two colleagues published an updated paper in the *Journal of Applied Physiology* titled “The Two-Hour Marathon: Who and When?” the idea no longer seemed ridiculous. In fact, the journal published an unprecedented thirty-eight responses from other researchers, speculating on the various factors that might bring the barrier closer. In late 2014, shortly after Dennis Kimetto of Kenya posted the first sub-2:03, a consortium led by a British sports scientist named Yannis Pitsiladis announced plans to break the two-hour barrier within five years.

Still, two minutes and fifty-seven seconds remained a substantial gap. Also in 2014, *Runner’s World* magazine asked me to undertake a comprehensive analysis of the physiological,

psychological, and environmental factors that would need to come together for someone to run a two-hour marathon. After reviewing mountains of data and consulting experts around the world, including Joyner, I presented ten pages of charts, graphs, maps, and arguments, concluding with my own prediction: the barrier would fall, I wrote, in 2075.

That prediction leapt immediately to mind in October 2016, when I got an unexpected call from David Willey, then the editor in chief of *Runner's World*. Nike, the biggest sports brand in the world, was preparing to unveil a “top-secret” project that aimed to deliver a sub-two marathon in just six months. We were being offered the opportunity to go behind the scenes to cover the initiative, which they’d dubbed Breaking2. I didn’t know whether to laugh or roll my eyes, but I couldn’t say no. I agreed to fly to Nike’s headquarters, in the Portland, Oregon, suburb of Beaverton, a few weeks later to hear their pitch. If someone had to debunk an overhyped marketing exercise, I figured the research for my earlier *Runner's World* piece had left me as well equipped as anyone.

As my guest spot on the television broadcast wraps up, Kipchoge hits twenty-three miles. It’s May 6, 2017, exactly sixty-three years to the day after Roger Bannister ran the first sub-four-minute mile. I’m nearly frantic to get track-side now—but I’m not sure how to get down from my lofty perch in the broadcast booth. Peering over the edge, I briefly contemplate swinging myself over the railing and risking the drop. But a stern glance

from a nearby security guard dissuades me. Instead, I head back over the causeway that connects the broadcast booth to the main building's multistory maze of dead-end hallways and unlabeled doors. I don't have time to wait for a guide. I break into a run.

Part I

CHAPTER 1

The Unforgiving Minute

*If you can fill the unforgiving minute
With sixty seconds' worth of distance run,
Yours is the Earth and everything that's in it*
—RUDYARD KIPLING

On a frigid Saturday night in the university town of Sherbrooke, Quebec, in February 1996, I was pondering—yet again—one of the great enigmas of endurance: John Landy. The stocky Australian is one of the most famous bridesmaids in sport, the second man in history to run a sub-four-minute mile. In the spring of 1954, after years of concerted effort, centuries of timed races, millennia of evolution, Roger Bannister beat him to it by just forty-six days. The enduring image of Landy, immortalized in countless posters and a larger-than-life bronze statue in Vancouver, British Columbia, comes from later that summer, at the Empire Games, when the world's only four-minute milers clashed head-to-head for the first and only time. Having led the entire race, Landy glanced over his left shoulder as he entered the final straightaway—just as Bannister edged past on his right. That split-second tableau of defeat confirmed him as, in the words of a British newspaper headline, the quintessential “nearly man.”

But Landy's enigma isn't that he wasn't quite good enough. It's that he clearly was. In pursuit of the record, he had run 4:02 on six different occasions, and eventually declared, "Frankly, I think the four-minute mile is beyond my capabilities. Two seconds may not sound much, but to me it's like trying to break through a brick wall." Then, less than two months after Bannister blazed the trail, Landy ran 3:57.9 (his official mark in the record books is 3:58.0, since times were rounded to the nearest fifth of a second in that era), cleaving almost four seconds off his previous best and finishing 15 yards ahead of four-minute pace—a puzzlingly rapid, and bittersweet, transformation.

Like many milers before me and since, I was a Bannister disciple, with a creased and nearly memorized copy of his autobiography in permanent residence on my bedside table; but in that winter of 1996 I was seeing more and more Landy when I looked in the mirror. Since the age of fifteen, I'd been pursuing my own, lesser four-minute barrier—for 1,500 meters, a race that's about 17 seconds shorter than a mile. I ran 4:02 in high school, and then, like Landy, hit a wall, running similar times again and again over the next four years. Now, as a twenty-year-old junior at McGill University, I was starting to face the possibility that I'd squeezed out every second my body had to offer. During the long bus ride from Montreal to Sherbrooke, where my teammates and I were headed for a meaningless early-season race on one of the slowest tracks in Canada, I remember staring out the window into the swirling snow and wondering

if my long-sought moment of Landyesque transformation would ever arrive.

The story we'd heard, possibly apocryphal, was that the job of designing the Sherbrooke indoor track had been assigned to the university's engineering department as a student project. Tasked with calculating the optimal angles for a 200-meter track, they'd plugged in numbers corresponding to the centripetal acceleration experienced by world-class 200-meter sprinters—forgetting the key fact that some people might want to run more than one lap at a time. The result was more like a cycling velodrome than a running track, with banks so steep that even most sprinters couldn't run in the outside lanes without tumbling inward. For middle-distance runners like me, even the inside lane was ankle-breakingly awkward; races longer than a mile had to be held on the warm-up loop around the inside of the track.

To break four minutes, I would need to execute a perfectly calibrated run, pacing each lap just two-tenths of a second faster than my best time of 4:01.7. Sherbrooke, with its amusement-park track and an absence of good competition, was not the place for this supreme effort, I decided. Instead, I would run as easily as possible and save my energy for the following week. Then, in the race before mine, I watched my teammate Tandra Dunn sprint fearlessly to an enormous early lead in the women's 1,500, click off lap after metronomic lap all alone, and finish with a scorching personal best time that qualified her for the national collegiate championships. Suddenly my obsessive calculating and endless

strategizing seemed ridiculous and overwrought. I was here to run a race; why not just run as hard as I could?

Reaching the “limits of endurance” is a concept that seems yawningly obvious, until you actually try to explain it. Had you asked me in 1996 what was holding me back from sub-four, I would have mumbled something about maximal heart rate, lung capacity, slow-twitch muscle fibers, lactic acid accumulation, and various other buzzwords I’d picked up from the running magazines I devoured. On closer examination, though, none of those explanations hold up. You can hit the wall with a heart rate well below max, modest lactate levels, and muscles that still twitch on demand. To their frustration, physiologists have found that the will to endure can’t be reliably tied to any single physiological variable.

Part of the challenge is that endurance is a conceptual Swiss Army knife. It’s what you need to finish a marathon; it’s also what enables you to keep your sanity during a cross-country flight crammed into the economy cabin with a flock of angry toddlers. The use of the word *endurance* in the latter case may seem metaphorical, but the distinction between physical and psychological endurance is actually less clear-cut than it appears. Think of Ernest Shackleton’s ill-fated Antarctic expedition, and the crew’s two-year struggle for survival after their ship, the *Endurance*, was crushed in the ice in 1915. Was it the toddlers-on-a-plane type of endurance that enabled them to persevere, or straightforward physical fortitude? Can you have one without the

other?

A suitably versatile definition that I like, borrowing from researcher Samuele Marcora, is that endurance is “the struggle to continue against a mounting desire to stop.” That’s actually Marcora’s description of “effort” rather than endurance (a distinction we’ll explore further in Chapter 4), but it captures both the physical and mental aspects of endurance. What’s crucial is the need to override what your instincts are telling you to do (slow down, back off, give up), and the sense of elapsed time. Taking a punch without flinching requires self-control, but endurance implies something more sustained: holding your finger in the flame long enough to feel the heat; filling the unforgiving minute with sixty seconds’ worth of distance run.

The time that elapses can be seconds, or it can be years. During the 2015 National Basketball Association playoffs, LeBron James’s biggest foe was—with all due respect to Golden State defender Andre Iguodala—fatigue. He’d played 17,860 minutes in the preceding five seasons, more than 2,000 minutes ahead of anyone else in the league. In the semis, he surprisingly asked to be pulled from a game during a tense overtime period, changed his mind, drained a three-pointer followed by a running jumper with 12.8 seconds left to seal the victory, then collapsed to the floor in a widely meme-ified swoon after the buzzer. By Game 4 of the finals, he could barely move: “I gassed out,” he admitted after being held scoreless in the final quarter. It’s not that he was acutely out of breath; it was the steady drip of fatigue

accumulating over days, weeks, and months that just as surely pushed James to the limits of his endurance.

At the opposite end of the spectrum, even the greatest sprinters in the world fight against what John Smith, the coach of former 100-meter world-record holder Maurice Greene, euphemistically calls the “Negative Acceleration Phase.” The race may be over in ten seconds, but most sprinters hit their top speed after 50 to 60 meters, sustain it briefly, then start to fade. Usain Bolt’s ability to stride magisterially away from his competitors at the end of a race? A testament to his endurance: he’s slowing down a little less (or a little later) than everyone else. In Bolt’s 9.58-second world-record race at the 2009 World Championships in Berlin, his last 20 meters was five hundredths of a second slower than the previous 20 meters, but he still extended his lead over the rest of the field.

At the same world championships, Bolt went on to set the 200-meter world record with a time of 19.19 seconds. A crucial detail: he ran the first half of the race in 9.92 seconds—an amazing time, considering the 200 starts on a curve, but still slower than his 100-meter record. It’s barely perceptible, but he was pacing himself, deliberately spreading his energy out to maximize his performance over the whole distance. This is why the psychology and physiology of endurance are inextricably linked: any task lasting longer than a dozen or so seconds requires decisions, whether conscious or unconscious, on how hard to push and when. Even in repeated all-out weightlifting efforts—

brief five-second pulls that you'd think would be a pure measure of muscular force—studies have found that we can't avoid pacing ourselves: your “maximum” force depends on how many reps you think you have left.

This inescapable importance of pacing is why endurance athletes are obsessed with their splits. As John L. Parker Jr. wrote in his cult running classic, *Once a Runner*, “A runner is a miser, spending the pennies of his energy with great stinginess, constantly wanting to know how much he has spent and how much longer he will be expected to pay. He wants to be broke at precisely the moment he no longer needs his coin.” In my race in Sherbrooke, I knew I needed to run each 200-meter lap in just under 32 seconds in order to break four minutes, and I had spent countless training hours learning the feel of this exact pace. So it was a shock, an eye-widening physical jolt to my system, to hear the timekeeper call out, as I completed my first circuit of the track, “Twenty-seven!”

The science of how we pace ourselves turns out to be surprisingly complex (as we'll see in later chapters). You judge what's sustainable based not only on how you feel, but on how that feeling compares to how you expected to feel at that point in the race. As I started my second lap, I had to reconcile two conflicting inputs: the intellectual knowledge that I had set off at a recklessly fast pace, and the subjective sense that I felt surprisingly, exhilaratingly good. I fought off the panicked urge to slow down, and came through the second lap in 57 seconds—

and still felt good. Now I knew for sure that something special was happening.

As the race proceeded, I stopped paying attention to the split times. They were so far ahead of the 4:00 schedule I'd memorized that they no longer conveyed any useful information. I simply ran, hoping to reach the finish before the gravitational pull of reality reasserted its grip on my legs. I crossed the line in 3 minutes, 52.7 seconds, a personal best by a full nine seconds. In that one race, I'd improved more than my cumulative improvement since my first season of running, five years earlier. Poring through my training logs—as I did that night, and have many times since—revealed no hint of the breakthrough to come. My workouts suggested, at most, incremental gains compared to previous years.

After the race, I debriefed with a teammate who had timed my lap splits for me. His watch told a very different story of the race. My first lap had taken 30 seconds, not 27; my second lap was 60, not 57. Perhaps the lap counter calling the splits at the finish had started his watch three seconds late; or perhaps his effort to translate on the fly from French to English for my benefit had resulted in a delay of a few seconds. Either way, he'd misled me into believing that I was running faster than I really was, while feeling unaccountably good. As a result, I'd unshackled myself from my pre-race expectations and run a race nobody could have predicted.

After Roger Bannister came the deluge—at least, that's how

the story is often told. Typical of the genre is *The Winning Mind Set*, a 2006 self-help book by Jim Brault and Kevin Seaman, which uses Bannister's four-minute mile as a parable about the importance of self-belief. "[W]ithin one year, 37 others did the same thing," they write. "In the year after that, over 300 runners ran a mile in less than four minutes." Similar larger-than-life (that is, utterly fictitious) claims are a staple in motivational seminars and across the Web: once Bannister showed the way, others suddenly brushed away their mental barriers and unlocked their true potential.

As interest in the prospects of a sub-two-hour marathon heats up, this narrative crops up frequently as evidence that the new challenge, too, is primarily psychological. Skeptics, meanwhile, assert that belief has nothing to do with it—that humans, in their current form, are simply incapable of running that fast for that long. The debate, like its predecessor six decades ago, offers a compelling real-world test bed for exploring the various theories about endurance and human limits that scientists are currently investigating. But to draw any meaningful conclusions, it's important to get the facts right. For one thing, Landy was the only other person to join the sub-four club within a year of Bannister's run, and just four others followed the next year. It wasn't until 1979, more than twenty years later, that Spanish star José Luis González became the three hundredth man to break the barrier.

And there's more to Landy's sudden breakthrough, after being

stuck for so many races, than simple mind over muscle. His six near-misses all came at low-key meets in Australia where competition was sparse and weather often unfavorable. He finally embarked on the long voyage to Europe, where tracks were fast and competition plentiful, in the spring of 1954—only to discover, just three days after he arrived, that Bannister had already beaten him to the goal. In Helsinki, he had a pacer for the first time, a local runner who led the first lap and a half at a brisk pace. And more important, he had real competition: Chris Chataway, one of the two men who had paced Bannister's sub-four run, was nipping at Landy's heels until partway through the final lap. It's not hard to believe that Landy would have broken four that day even if Roger Bannister had never existed.

Still, I can't entirely dismiss the mind's role—in no small part because of what happened in the wake of my own breakthrough. In my next attempt at the distance after Sherbrooke, I ran 3:49. In the race after that, I crossed the line, as confused as I was exhilarated, in 3:44, qualifying me for that summer's Olympic Trials. In the space of three races, I'd somehow been transformed. The TV coverage of the 1996 trials is on YouTube, and as the camera lingers on me before the start of the 1,500 final (I'm lined up next to Graham Hood, the Canadian record-holder at the time), you can see that I'm still not quite sure how I got there. My eyes keep darting around in panic, as if I expect to glance down and discover that I'm still in my pajamas.

I spent a lot of time over the next decade chasing further

breakthroughs, with decidedly mixed results. Knowing (or believing) that your ultimate limits are all in your head doesn't make them any less real in the heat of a race. And it doesn't mean you can simply decide to change them. If anything, my head held me back as often as it pushed me forward during those years, to my frustration and befuddlement. "It should be mathematical," is how U.S. Olympic runner Ian Dobson described the struggle to understand the ups and downs of his own performances, "but it's not." I, too, kept searching for the formula—the one that would allow me to calculate, once and for all, my limits. If I knew that I had run as fast as my body was capable of, I reasoned, I'd be able to walk away from the sport with no regrets.

At twenty-eight, after an ill-timed stress fracture in my sacrum three months before the 2004 Olympic Trials, I finally decided to move on. I returned to school for a journalism degree, and then started out as a general assignment reporter with a newspaper in Ottawa. But I found myself drawn back to the same lingering questions. Why wasn't it mathematical? What held me back from breaking four for so long, and what changed when I did? I left the newspaper and started writing as a freelancer about endurance sports—not so much about who won and who lost, but about why. I dug into the scientific literature and discovered that there was a vigorous (and sometimes rancorous) ongoing debate about those very questions.

Physiologists spent most of the twentieth century on an epic quest to understand how our bodies fatigue. They cut the hind

legs off frogs and jolted the severed muscles with electricity until they stopped twitching; lugged cumbersome lab equipment on expeditions to remote Andean peaks; and pushed thousands of volunteers to exhaustion on treadmills, in heat chambers, and on every drug you can think of. What emerged was a mechanistic—almost mathematical—view of human limits: like a car with a brick on its gas pedal, you go until the tank runs out of gas or the radiator boils over, then you stop.

But that's not the whole picture. With the rise of sophisticated techniques to measure and manipulate the brain, researchers are finally getting a glimpse of what's happening in our neurons and synapses when we're pushed to our limits. It turns out that, whether it's heat or cold, hunger or thirst, or muscles screaming with the supposed poison of "lactic acid," what matters in many cases is how the brain interprets these distress signals. With new understanding of the brain's role come new—and sometimes worrisome—opportunities. At its Santa Monica, California, headquarters, Red Bull has experimented with transcranial direct-current stimulation, applying a jolt of electricity through electrodes to the brains of elite triathletes and cyclists, seeking a competitive edge. The British military has funded studies of computer-based brain training protocols to enhance the endurance of its troops, with startling results. And even subliminal messages can help or hurt your endurance: a picture of a smiling face, flashed in 16-millisecond bursts, boosts cycling performance by 12 percent compared to frowning faces.

Over the past decade, I've traveled to labs in Europe, South Africa, Australia, and across North America, and spoken to hundreds of scientists, coaches, and athletes who share my obsession with decoding the mysteries of endurance. I started out with the hunch that the brain would play a bigger role than generally acknowledged. That turned out to be true, but not in the simple it's-all-in-your-head manner of self-help books. Instead, brain and body are fundamentally intertwined, and to understand what defines your limits under any particular set of circumstances, you have to consider them both together. That's what the scientists described in the following pages have been doing, and the surprising results of their research suggest to me that, when it comes to pushing our limits, we're just getting started.

Конец ознакомительного фрагмента.

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