

FASTER

The Obsession, Science and Luck
Behind the World's Fastest Cyclists



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B L O O M S B U R Y

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INTRODUCTION

An accidental athlete

We all make sacrifices to feed our passions. In my case, I can barely remember the last time I spent the night anywhere other than in a tent. This would be understandable were I a survivalist, a Bedouin, or a terminally lost arctic-explorer, but I'm not. I'm a cyclist.

The tent is in my bedroom, which most people seem to feel makes things not quite as adventurous but no less peculiar. I sleep in it because it simulates high altitude – the air inside has been pumped through a filtration system to reduce the oxygen content from the normal sea level 20.8% to something more like 14%. It's the equivalent of 3,500m, further up than Europe's highest mountain pass. Sleeping at 'altitude' this way is supposed to give you most of the benefits of altitude training without the inconvenience of living and working at the top of an Alp for 12 months of the year, or moving to Albuquerque.

That's not to say there are no downsides at all. The pump makes a noise like an outboard motor. On a warm night the temperature inside the tent can climb into the unbearable, and on a cold one the condensation drips down the inside until it saturates the sheets and I end up trying to sleep on a thin sliver of dry in the middle of the bed. If I run a small fan inside the tent it can help with the heat and condensation problems, but then the noise of that combines with the outboard motor to replicate the effect of sleeping on an airliner.

The other inconvenience is my partner. Her first introduction to the tent was when she got home from work one night to find it already fully installed. I hadn't had the nerve to mention it. I suppose I hoped the surprise of finding it would distract her from the surprise of how much money had vanished from our bank account to pay for it. Since we lived in a one-bedroom flat she was either going to have to share it, sleep on the sofa, or just cut her losses and get out of the whole relationship.

I didn't show her the bit of the instruction manual that promised suffocation to those who attempted to share the limited air supply. The way I saw it, the less air there was to go around, the higher the effective altitude, and at no extra cost. I was untroubled by how closely this was related to the plastic bag-over-the-head altitude-simulation system. This was simply because the tent was something that might help me ride a bike faster. I already trained more or less all day – now I could use those wasted hours of sleep to sneak another gain. I'd have bought the tent even if the warning was one of a random 30% chance of sudden death. Anything for speed.

I like to think that none of the foregoing would make anyone question my sanity. But even I have to admit that a rational man would have his doubts when I say that to this day I have no idea whether the tent and all its associated costs and aggravations actually made me any faster. The theory is sound, there have been a few reasonably good scientific studies, but even the best of those only claims

makes a relatively small difference, for some people, sometimes. For me, perhaps multiplied by perhaps is enough.

It's not just the tent. In the same period I rode somewhere around 175,000 miles. I owned around 5 bikes, each one of which I was convinced was going to go faster than the previous one. I even spent morning riding round Manchester Velodrome's track in the nude in an attempt to find out if bare skin was faster than a Lycra suit. (It wasn't, and thank God for that.)

I spent hours in laboratories being tested and measured. I'm an unusual physical specimen, so there was never any shortage of physiologists keen to poke and prod. I found out all manner of unlikely things about myself – I had what was reckoned to be just about the highest ratio of lung-capacity to height measured in a UK lab, for instance – that would have made interesting, if creepy, conversational starters at parties if I had not been so scared of catching a cold that I avoided parties at all costs, along with cinemas, and concerts. I sat on planes with a polo-neck jumper pulled up to just below my eyes like Wilfrid from the *Bash Street Kids*.

I lived in a world where, one way or another, everything was divided into things that might make me faster and things that might make me slower. Pretty much anything pleasant fell into the second category. Eating sensibly makes you faster. A couple of beers make you slower. A quiet evening with your feet up to recover from a hard day on the bike makes you faster. A night out with your friends makes you slower. But misery and loneliness make you slower too. You don't have to be happy, and you almost certainly aren't, but you have to be able to function sufficiently to get up, have a kilo of porridge for breakfast, and get on your bike. Even the most committed have to choose between speed and sanity. So the question is: how much more committed will you be to next week's workload if you go out for a drink, and try to get riding right, eating right and thinking right out of your mind for an hour or two? Will you lose 3% of the week's progress, but gain 4%? Always running in the background is an app that asks, 'How do I go faster?'

I never meant for any of this to happen. I never even wanted to be an athlete. My ambition was to be an academic lawyer, and by my mid-twenties that's exactly what I was. I taught slightly left-wing civil liberties and human rights courses to first-year undergraduates at Sussex University. Since most of the students had their hearts set on becoming big-shot lawyers for major corporations, my job was overshadowed by the unspoken irony that my flock was almost certainly going to spend more time oppressing minorities than defending them.

I wasn't really too bothered by this, nor by knowing that they'd earn five times my salary while they did it. But I was driven to despair by the interminable Wednesday afternoon meetings of the faculty staff. Hours spent achieving nothing in an airless 1960s seminar room where the unjustified use of a gender-specific pronoun was fighting talk. We would debate such things as the political significance of the sign on the women's toilet featuring a figure standing legs-together, and the men's featuring one standing legs-apart. Or rather, older members of the faculty would debate it, while I and a couple of the younger members of staff would pass each other sarcastic notes about them under the table.

By then I'd been cycling for a couple of years, and I was getting quite good at it. I'd begun spending my weekends travelling up and down the UK to national-level races. I often abandoned work at lunchtime to do a few hours training, making up the time by working into the night. I resented every minute spent in the faculty meeting because it was a minute I wasn't on my bike. This quickly progressed to resenting every minute of my job because it was a minute I wasn't on my bike. My contract came up for renewal, and I don't think I even bothered going to the interview. Maybe it happened one Wednesday afternoon while I was down the corridor trying to work out which toilet to use.

I went to a research job at a different university. Or rather I took the money and the accommodation, and spent my time cycling. A successful season followed. A bike manufacturer offered me a contract to go full-time. The money wasn't great, and it would almost certainly be the ruin of my proper career,¹ but I said yes anyway. The obsession with faster had taken hold, and the chance to work at it undistracted by any more grown-up responsibilities was too much to resist. In some ways nothing I've done since in the pursuit of speed has been quite as irrational.

It led me into an odd career. I was a time-trial specialist, and I was in the only country in the world where you could conceivably make a living doing that. Unlike everywhere else, in the first few years of the twenty-first century the UK was still obsessed with time trialling as the bedrock of the sport. Time trialling suited me perfectly. Unlike mass-start road racing, TTing is an event for the analytical. It rewards hard work, knowledge and research. It's about control, in racing and training, about measuring effort perfectly, and concentrating on what you're doing.

It's not mercurial. It's not especially interesting to watch, if I'm honest, at least not for a casual spectator. But it's the purest form of bike racing, and it finds the strongest riders. It's about speed, and nothing more. If you want to win a time trial, all you have to do is be the fastest rider in the race. There are no tactics, no teams, just you. From the inside it is fascinating, and it fascinated me.

There was another reason I was happy with it. My career coincided with the dirtiest era in international pro cycling. That was where my background probably made a very serious difference to my riding. I didn't grow up as a star-struck kid dreaming of a life in cycling, or in any other sport. I stumbled into it almost by accident, and at an age where I was quickly under no illusions about how pro cycling worked. I didn't have hopes dashed, or agonising choices to make between my dreams and my honesty.

I knew what that world was like, and I wanted nothing to do with it. A friend of a friend went to Italy to try to carve out a career, and came back a few weeks later in despair. 'You can cheat or you can lose,' was his comment. 'Your choice.' Like a lot of honest riders of that era, I was a victim of the doping that was rampant. At the time I didn't really mind, because I had other options in life. I didn't feel trapped or disappointed. I just felt content to be scratching a living doing something I'd otherwise have been doing for nothing.

As time has passed I've come to resent it more. I can't help thinking that in a different time, or even in a different sport, I could have been a star. Towards the end of my career I've become more competitive against the world's best riders than I ever was in my prime because the world's fastest bike riders are not quite as fast as once they were. The sport is finally making inroads against doping and you can see it in the fact that since about 2006 the top pros have slowed down. Ten years ago, if I went to race a time trial against the very top riders I got beaten by margins that you could mark out on a calendar. In the last few seasons, it's down to a something you can measure in seconds, with perhaps even the occasional win.

I didn't really mind at the time, though, and I'm not sure there's a lot to be gained by minding now. I'm grateful that, for the moment at least, the sport has moved a long way in the right direction, and that young riders can find honest role models.

In my analytical little time-trial specialism I won more than 50 British titles over various distances and as a dual-national I also won the Irish championships. I set numerous national records, including one that I took from Bradley Wiggins, was placed fourth at the Commonwealth Games on two occasions, and rode at the World Championships. I might not have reached the very top, but what I did do was clean, properly clean, and however self-congratulatory it might sound, I'm proud of that. I was and I still am, a very fast bike rider.

The first question is: why? What is it about me that makes me faster than the vast majority of bike

riders? Is it physical? Mental? Is it something innate, or something I achieved by training? There was a phase early in my career when I was so terrified that whatever it was might suddenly vanish that my first race of the year was a source of acute pre-event anxiety. Whatever it is was always there when I needed it, but that doesn't solve the mystery of where it came from in the first place.

The second question is: why are a lucky few faster than me? Is it just more of the same thing that makes me faster than everyone else?

The third question is: can I do anything to catch them?

These questions have had a hold over me for the last decade and a half – a large proportion of my adult life. It's no sensible preoccupation for a grown man, I know that. But I can't help it.

At least I'm not alone. Over the last few seasons I've had more and more people to keep me company in my obsession. For those of us interested in drug-free speed, the reduction in doping has had significant consequences. As one coach put it to me, 'Six or seven years ago, who the hell was going to look for a 1% gain from better training if they could inject a 10% gain with better drugs?' If you wanted to go faster, in a sport with a doping culture, pharmaceuticals were always going to be the most cost-effective place to spend your time and money.

One of the sport's more powerful players gave it a broader context: 'Ten years ago, a team's budget comprised one-third rider salaries, one-third logistics, and one-third drugs. The core skills were pharmacology, doctors, how to avoid detection, and how to move the whole operation around the world without getting caught. The teams were very good at this. But most of them had very little knowledge of genuine coaching and conditioning of riders. Then in the last few years, teams have had to get out of the systematic doping game. There's a third of the budget going spare. A lot of them spent it on rider salaries. But some of them spent it on coaching, equipment, sports science support.'

In short, there has never, in the whole chequered history of cycling, been more interest in non-pharmaceutical ways to make riders go faster than there has been in the last few years. Ten years ago a lot of clean amateurs had a more sophisticated grasp of training, aerodynamics and associated areas than the top pro teams did, because the top pro teams had better (for which read 'worse') things to worry about. In many ways, pro cycling has become much more like amateur cycling, or like the kind of thing I've been doing all my life.

The idea that the doping culture meant that every other aspect of cycling performance was underdeveloped is one that I found was supported by almost all the sports scientists and coaches that I talked to, from within cycling as well as without.

Sir Dave Brailsford, the boss at Team Sky, accepted that this backdrop was part of the reason for their success: 'In a sense it was a fluke, the sport was cleaning itself up just as we arrived, with a different skillset that we transferred from the national-squad track programme. We spent less on big-name riders, and more on full-time coaches, performance analysis, psychology, and sports science.'

It's not surprising that Team Sky would want to take as much from the Team GB approach as they could – the GB squad has been quite outrageously successful over the last few Olympic cycles. It probably been the most successful sporting campaign in history. The sudden availability of lottery funding from the late 1990s onward was certainly the basis for it, but the money wasn't infinite, and it was spent efficiently.

The lottery cash was aimed at generating Olympic success, following a national panic after the 1996 Games when the British team came home with just a single gold medal. Since Steve Redgrave and Matthew Pinsent were such unsurprising winners the medal almost didn't count. Peter Keen, the first director of the new-look GB cycling team, concentrated exclusively on the events where he reckoned Olympic medals were easiest to win. That meant staying away from the road entirely – too many drugs, and tactics-dominated racing that was too unpredictable – and putting all the resources in track racing, which by the late 1990s was a backwater that no nation had invested in properly since the

fall of the Iron Curtain.

It was more focused even than that – the investment went into the quantifiable, controllable even with the lowest possible risk. The 1km time trial, the team sprint, the individual pursuit and the team pursuit got the cash, because they were races of pure speed. Other events, like the match sprint and the points race, which depend on tactics and a bit of luck, were largely ignored. If it didn't generate a number for the spreadsheet, it didn't get done. It was a ruthless, lean system designed to turn money into medals.

I was, for a while, a handful of cells on the spreadsheet. I spent a couple of years not quite on, not quite off the track squad. To get properly on to the squad, I had to make a qualifying standard time of 4'30" over a 4,000m pursuit. It was obvious to the coaches that I had the capacity to do this, but though I repeatedly got to within a few tenths of a second of it, I never quite made it. The head coach at the time tried manfully to get me the last few yards. He kept me around the programme longer than he probably should have done. But it never happened.

My problem was, ironically, that I was a professional rider on the road. My success there depended on judging a sustainable time trial effort over distances much longer than 4,000m, and I was too good at it. I struggled very badly to raise my pace above the effort levels that I knew so well, because even when I pushed properly into the red zone all my carefully trained alarm bells went off.

With hindsight, what I should have done was abandon the road career, give up that income, and focus on the track. If I'd done that, I'd have made the time, got myself on the squad, got the resulting funding, and more to the point, got access to the coaching and support that was available. I didn't. It was a huge mistake.

I got to watch a lot of people I'd ridden with, gone on training camps with, winning medals at the 2004 and 2008 Olympics. They had the opportunity to do that because they produced the results for the spreadsheet when it mattered. I knew that was how it worked when I got involved, so it was not one's fault but my own.

This is the sharp end of a team. The aim is for the team to win medals, not to help any given individual make the most of themselves. It's Darwinian. When I interviewed Shane Sutton, the head coach of the GB team for London 2012, he said simply, 'I'm trying to win medals, to get the funding to make sure all these people have a bloody job next year.' He gestured round an office full of team staff. 'It's the system that has to win.'

The system lived by what became known as 'the aggregation of marginal gains'. It's a phrase that seems to mean different things to different people. I think the simplest understanding of it is that it's about looking for any way to go faster, however big, however small, and it works by breaking everything down into its component elements to see if you can make any improvement to any one of them. One comparison might be the script room of a major US sitcom. The writers don't look at the whole show and ask if it's funny enough, they take the script to bits, look at every scene and even every single line, and no matter how funny it might already be, they ask whether there is any way to make it funnier, all the way down to the individual words.

So 'marginal gains' doesn't just look at diet, it looks at diet before training, during training and after training. Then before, during and after one-day races. Then how that regime would have to be altered to deal with the different demands of stage races and Grand Tours. It looks at how to serve up what's required in a way that makes it easy for an athlete to eat it. Ultimately it hires a chef, because that's the only way 'marginal gains' can solve all the problems of the right nutrients in the right form in the right place at the right time.

'Marginal gains' doesn't just exhort riders to have a good night's sleep – it examines the position of training and racing routines and commitments that affect bed-times, it researches the best earplugs, it buys eye-masks and MP3 files of rainforest sounds, and it packs each rider's pillows into the back of

van and drives them to the hotel.

~~'Marginal gains' doesn't give a toss what anyone else thinks.~~ Team Sky decided that since the first step to good post-race recovery was a warm-down, they'd make sure that for races that finished with a flat-out effort, like a hill-top finish, the riders would get on to stationary trainers after they'd finished and warm down properly. The reaction from other teams was unrestrained mirth, at least for the two or three months it took for them to start doing the same thing.

It's not really the gains that are marginal – some will be small, but some will be big. It's where you go looking that's marginal, peering into every nook and cranny of cycling. In the run-in to 2012, the GB track team looked at plenty of things that ultimately turned out to be unimprovable, or at least not worth the effort without creating considerable knock-on difficulties. Wheel nuts could be made more aerodynamic, for example, but only at the cost of being almost impossible for the mechanics to work with when the pressure was on.

You have to keep looking, all the time. Sport moves on. It gets better, it gets faster. If you stop to catch your breath, you go backwards. I always reckon I need to find about 2% a year from somewhere just to stay where I am in the pecking order. Until I find that 2% I'm not even making any real progress.

It's not a unique approach. One senior businessman working on a programme for the BBC went to British Cycling's base at Manchester Velodrome after the 2008 Games to see what lessons industry might learn from the team. He concluded that what was going on there wasn't very different from what the most successful businesses were already doing. But it was new to cycling, and it changed things.

Ultimately, I didn't ever make it to the very top of the sport. In an odd way, I'm grateful for that. It meant that I ended up focusing on the personal rewards of chasing excellence rather than on the financial ones, and I avoided the pressures that would have brought. There was always something to be said for being able to do more or less what I wanted. As I approach retirement, of course, I can't help but feel there might equally have been something to be said for the big house and the investment portfolio, but I try not to dwell on it.

My perch just below the summit of the mountain is a wonderful outlook if you want a perspective on the quest for faster. Chris Boardman pointed out to me during an interview that, 'At least you know what it's like.' He meant, generously, that I knew what it was like to compete at the top level, to have that all-consuming passion, to live a life governed by a stopwatch. But I also know what it's like to look up at the very best and wonder how they got there. I know how to win, and I know how to lose. If you don't learn more from losing than you do from winning, you're not doing it right.

This book was an excuse to write down all the things I've been worrying about for all these years. It was also an excuse to ask the best riders, coaches and sports scientists about what made the fast riders so damn fast. I learned a very great deal, and rather more than I expected. Partly this was because I knew less than I thought I did, and partly it was because in recent seasons things have moved on more and more quickly. I was surprised, and delighted, at the detail most of those I spoke to were prepared to go into about what they do. More than one rider said they were happy to tell me what they were doing because just knowing what it was wasn't enough. You had to be able to *actually* do it.

Most people only see elite sport in its moments of glory. They never hear about the nether regions where the work gets done. Paul Manning, gold medallist in the team pursuit in Beijing, and coach of the women's endurance track squad at London, said that he reckoned at least 95% of the coaches' and riders' jobs had already been done before they even walked into the track for the first rounds of competition.

I'm not going to deal with the racing and the glory. I'm going to deal with the 95%, the basics of

what makes an athlete. What it is about their physiology that allows them to do what they do, and how they came to be built that way. How they do their jobs, and deal with not just the pressures of competition, but how they motivate themselves when being a star consists of a wretched seven-hour ride through the freezing January drizzle. I'm going to look at the technical issues of aerodynamics that have become more and more prominent, and, finally I'm going to deal with the way genetics underpins all of human performance.

It's worth saying that this book is not intended to be a manual. It's not sufficiently comprehensive. There are certainly some things that the elite riders do that could be applied by anyone, but most of the book focuses on the small margins that separate the Olympic gold medallists and world champions from the athletes who were right behind them. To be blunt, for most riders it would be pointless to worry too much about the last tenth of performance gains until they've dealt with the first nine. As Olympic coach Dan Hunt said, 'It's a waste of time drinking organic cherry juice if you're using it to wash down a Big Mac.'

What the book does illustrate, I hope, is just what's possible when resources and ingenuity are brought to bear on the simple act of riding a bike.

CHAPTER 1

Like a racehorse: the art of being an athlete

One winter night, heading home after meeting some friends in a London pub, I caught the last train from King's Cross to Cambridgeshire. To avoid falling asleep and finishing up at the end of the line at King's Lynn, I took out some headphones and a notepad, and started to transcribe an interview with British pro Alex Dowsett.

Somewhere around Stevenage, I was concentrating on this when I saw a man in his early twenties coming over. He was already speaking when I took the headphones off. What he was saying finished with '...Alex Dowsett.' I'm confident the already slack jaw and the Sauvignon Blanc fumes managed to mask my confusion.

He'd been at school with Dowsett, and had recognised me as one of his friend's former opponents. He was an ex-international racer himself – when British Cycling's talent scouts had, in their best East German style, visited the school to check up on Dowsett, they'd picked him out of the crowd too. It had been a surprise. Cycling wasn't something he'd ever really thought about seriously.

'But they said they'd give me a decent bike, help me with training, enter me in a few races, and see how it went. I liked the idea,' he said. 'Who wouldn't?' He ended up racing as a junior at the World Mountain Bike Championships. He did well too, for a relative novice. The talent scouts had been right – he had what it took.

Or at any rate he had part of what it took. Why, I asked, had he given it up? It was simple, he said. He hadn't been an athlete. The excitement of racing hadn't made him want to spend months and years devoted to training. He'd been good at riding a bike, and that was all.

Dowsett, on the other hand, had been an athlete before the talent team even arrived. And while he and I and my friend and I pursued a slightly drunken (on my part anyway) conversation about bikes, books, and missed opportunities, somewhere in Essex he was sleeping the sleep of the going-to-get-up-in-the-morning-and-do-a-six-hour-training-ride.

There is a skill to being an athlete. It's not an easy job. You have to learn how to train. You have to learn how to work with a coach, and how to get the best out of whatever other support is available to you – something that quite possibly starts with finding that support in the first place. You have to manage a career, look after your body, and keep your motivation intact.

At what might seem like an absurdly basic level, you have to be able to tell when you're too tired. By any normal measure most athletes are very tired a lot of the time, and the edge that slips you into 'too tired' is almost imperceptible. 'Tired' isn't even a single feeling – fatigue comes in a hundred

varieties, all of which you learn to analyse for signs of danger. Nor does it help that the whole idea of 'too tired' moves depending on where in the training cycle you are. What might count as just 'quite tired' six weeks before a major event would be 'much, much too tired' a week before.

Before the London Paralympics, Dame Sarah Storey used a block of training in an altitude chamber. This wasn't something she'd done before. 'I had to do it almost by ear,' she said. 'You put your face close to the mirror every day, and ask yourself how you feel, how you really feel. Good? Bad? OK? That a twinge? Or am I imagining it? But it's no different to usual. Training is never the same twice. What was fine one season might be too much the next. You always have to ask yourself how you feel. Always.'

Equally you have to know when things are good. Dowsett's first big pro win was the time trial stage at the end of the Tour of Britain in 2011: 'I'd written off the TT because the week had been so hard. But when I stood up out of bed in the morning I knew my legs were good. I knew the day would be OK, so come the race I made sure I got everything out.'

No one can teach you this ability to read your own body. It comes only with experience. A coach can help, they can ask questions, and they can try either to make you play safe, or perhaps push you to go a bit deeper if they think you should be able to cope, but they can't know how it feels from inside.

It's the same with training. You can have all the help in the world, but you have to do it yourself. I'd be the first to point out that having time to spend on something as trivial as training is a considerable luxury, but doing it well, doing it all the way to your limits, is a very tough way to spend your days. That's how it works. Paul Manning won gold at the Beijing Olympics, and coached the Great Britain women's endurance squad in London. Referring to this squad, he said, 'Most people, most cyclists, even, have absolutely no concept of how hard they train. Laura Trott is sick after some of the efforts. There are jokes about the bucket we take to training sessions for her. She'll push that hard again and again in one session. It's masochistic. She loves what she does but she comes to the track to ride hard.'

Chris Hoy used to do his static trainer sessions with a crash mat beside the bike, on to which he would collapse in literal agony after an effort. Then he'd get up and repeat the process. This wasn't because he was in any way soft. It was because he was pushing himself to somewhere that only those who have practised doing it can ever reach. 'Back in the day,' he said, 'I used to do turbo trainer sessions. I'd set up in a stairwell at my parents' house, and I'd put myself through hell. Just on my own. No teammates for a bit of competition or anything. Just me. You can't rely on being inspired by anyone else. You have to want it yourself.'

It has to be hard. Time and time again I've asked star riders how they made the step up to the very top levels – I usually asked with a bit of an agenda because I felt as if it was the step they'd made and I hadn't. Almost always they said it was because somehow they'd found more within themselves with which to race and train. Often they were faced with a pro peloton that went faster than they'd believed possible. The speed of a race broke them through to a new place, a new 'hard' they never knew existed, but somewhere they could go back to on their own later.

Or maybe they grew up with a group of talented juniors, and they raised each other's expectations, work rates and tolerances: a group of teenagers who put themselves on the line again and again and moved their collective concept of the conventional on to higher and higher levels. The Isle of Man produced a group of outrageously good riders in the mid-to-late 2000s, including Mark Cavendish, and it wasn't a statistical anomaly.

The same thing can work on a broader scale. Sir Chris might have placed an emphasis on what you demand from yourself, but it's still hard to escape from the theory that part of the success of British Cycling over the last decade is the group of athletes training together at Manchester. Watching each other, seeing what a rival for a place on the team can lift in the gym, constantly measuring up against

each other, they create a bubble of their own extraordinary normality. It's a contrast to UK sports like athletics or swimming, where the athletes and their coaches are spread out over the country and only come together a few times a year. That's just competition, and that's not always enough.

I'm not sure how best to describe what the hard sessions are like. For a start, I'm not sure they feel the same for everyone, especially for sprinters when compared to endurance riders like me. I suspect that sprinters have to cope with more 'pain' (I'm not sure it's at all the right word – the sensations are not positive, even if they're not enjoyable in the sense that most people would understand it) but that endurance riders have to do it more often. But I might be wrong. Nor am I even sure that my experience is representative of everyone else, even if their physiology is broadly comparable.

I know that the way I trained changed over my first few seasons in the sport. I don't mean the content of the sessions, I mean how I did them. I came to cycling from a different endurance sport (rowing), so I wasn't totally green when I started. I think what distinguishes a hard session done well from a hard session done badly is the degree of control. When you've grown good at it, you can push to the limits of what you can do while staying so relaxed that you can wiggle your toes. There's no trace of a wild attack on the effort. You can feel what you're doing, and judge the effort level, even while your heart rate is at its maximum and your blood-lactate levels are heading for the roof. There's a detachment. You're not just piling everything on and hoping for the best.

In the last couple of seasons my training has included a session of 'all-out' sprint efforts, over 30 seconds. The idea is to start as fast as you possibly can, to hit what would effectively be the biggest power number you can hit under any circumstances, then just keep going as hard as you can manage until you're always hitting the biggest power number you're still capable of. The curve peaks after a couple of seconds, in my case at about 1,100 watts (or 1,100w), and then declines constantly for the rest of the 30 seconds until it gets to about 700w. Hence 'all-out' – it's not an evenly paced effort, it's about making sure you give everything you have. It sounds like a frenzy of effort, a spasm of sprinting. But when you do it well there is calmness and precision all the way through.

It's the same with other efforts – I do a 'pace-change' session of two minutes at 500w, a minute easy, a minute at 540w, a minute easy, and an all-out 30-second sprint. 500w for two minutes is the hard part of that – it's well above sustainable time trial pace. It's all I can do, and even then I can do a full set of repetitions only on my better days. But I'm still in control of what I'm doing. The 500w is 500w, it's not 490w or 510w. One of the Team Sky coaches said that their riders – especially those like Sir Bradley Wiggins with a track background – could do exactly the same. If a session calls for two minutes alternating between 510w and 450w, they'll nail the numbers and the transitions right up to the point when they just physically can't do it any more. On the computer screen afterwards, the power curve looks like a battlement.

It helps, of course, that for elite riders the numbers haven't been produced at random – they've been carefully worked out so that they're something very difficult but not impossible. Good coaches have a sense for where a rider's limits are. But hitting the numbers when the numbers are so demanding is a phenomenally skilful thing to be able to do, and it comes from years of practice.

That it 'hurts' is almost neither here nor there. You try to tolerate it, embrace it, put it in a box, luxuriate in it, turn your back and go to your happy place, deal with it in whatever other way you can. You have to go back again and again, and while you get better at it, it never gets easy. You need to listen to the sensations, because they tell you what's happening. But there are many times you need to do your best to just ignore it all, to go deeper, because that's part of learning how to train.

It's personal. Sports scientists have a scale of perceived exertion – named after the Swedish physiologist Gunnar Borg – that goes from six to 20: 11 is 'light'; 13 is 'somewhat hard'; 15 is 'hard'; 17 is 'very hard'; 19 is 'extremely hard' and 20 is 'maximal'.² I'm haunted in the night by the suspicion that what I think is a 20 is only a 15. Or that the people who are better than me got that wa

by the ability to hit 22, or 25 or 29. I once had some 'I've been to Borg 21' T-shirts made, but even the world of exercise physiology reckoned that was a joke too geeky.

I also worry that as I get older I've suffered from Borg inflation. I think that my ability to scale the heights of 19–20 improved as I learned to train, plateaued for several seasons, and is now in decline. I'm almost sure that my present-day 20 was only good for an 18 ten years ago. I've also developed a private suspicion that Gunnar Borg was just trying to make trouble inside the heads of people like me.

Training is not the only skill an athlete has to have. There are others that, even if they're not physically unforgiving, are as important. You have to be able to take coaching, to absorb a lot of information about what you're doing, and act on it. In 2011 Tim Kerrison, the performance analyst for Team Sky, started to push the importance of riding a negative split in time trials – making the second half a little harder than the first. It might not be the absolute A1 fastest way to do it, but it's the same way to get the whole effort out and the losses are minute compared to the benefits.

It's a little counter-intuitive for most riders. Some took this on board better than others – Wiggin was clearly putting it into practice at the Worlds that year and in the following season at the Tour and the Olympics. Dowsett (at that time a Sky rider) had always hit time trial efforts very hard from the beginning, and had more trouble with it. On one short prologue he hit a 470w average for the first half and 410w in the second. He admitted that Kerrison wasn't massively impressed.

My own coach and I worked out a similar strategy on our own. We based it on computer-modelling courses and producing an optimised plan for riding them. Simple physics dictates that there is a benefit to be had from riding harder on the climbs when the aerodynamic drag is lower. (The power needed to overcome aerodynamic drag in a race increases as the cube of speed – getting where you're going twice as fast is eight times as hard. Gravity, on the other hand, is a simple geometric increase – twice as fast is only twice as hard. You get better value for your anguish by pushing on the hills.)

The differences are subtle. The model accounted for gradients, for weather, and for the individual physiology of the rider – some of us are better at recovering from excursions into the red zone than others. Even allowing for all that, the typical variation in pace is usually no more than a very subtle 10% above or below an average pace.

Despite the effort that went into the model, it's not really possible to ride a time trial course by just staring at the numbers on a little screen on your bars. The first problem is that some days your form is better than others, and a danger is that you pick the wrong numbers. Pitch too low and you give away time. Pitch too high and you end up trying to sustain an impossible pace, with inevitably disastrous consequences. The second problem is the near impossibility of memorising maybe 50 different course segments and their corresponding power requirement. The third problem is getting sufficient accurate topographic data to feed into the model to begin with.

The art was in using the model as a guide, sitting down after a race with the computer file and compare it with the ideal to see where I got it right and where I got it wrong. I spent hours in front of a computer, relating the lines on the graph to the roads of the race, and the theory to the practice. I wanted to learn how to get it right just on feel. The differences are worth having – it depends very much on the details of the course and the physiology of the rider, but even on a relatively flat course you might find a second a kilometre just from laying down the right power in the right place.

This is the kind of thing with an inherent appeal only to the more nerdy end of the spectrum of riders. Most of them would rather just get on with riding their bikes. But anyone who is serious about riding a time trial has to work with the coaches and performance analysts and get used to it because it's a chance to go faster without having to find any extra physical grunt.

Sir Chris Hoy referred to this sort of thing as 'becoming a student of the sport'. You have to take it seriously, because the margins are so tight. Hoy's first world title, in 2002, was by one thousandth of a second – about 19mm over the course of a kilometre. He told me, 'You always want the be

information, you want to talk to the best people. You can go to the wind tunnel, you can see exactly what distance you can gain if you keep your head down and your elbows in. Then you go and look at a picture of yourself in the final stages of a sprint with your elbows sticking out. It's not easy to change a style you've used for years, but you have to fix things like that. I watch videos of the best guys from the past, the 1980s, the 1970s – how did they do it? What tactics did they use? You can never be satisfied – even after the 2008 Olympics I went back to look for any way I could have gone any faster. You never get there.'

When it comes to details, the Hoy elbows are just the tip of the iceberg. Qualifying for a mad sprint competition is a 200m flying-start time trial: 'You have to look at peak speed down to 0.1kph. Then you go back and look at where the optimal spot on the track is for the peak power, because every track is different. If your gear is too small, you'll hit peak power too soon, maybe even before reaching the 200m [start] line. When you get the gear right, then you have to apply the power in the right place – it might only vary by a couple of metres from one track to another, but you have to get it right. You need to know the temperature, the air pressure, because they matter too. You end up doing all this without really thinking about how subtle it is.'

When I was hanging around in Manchester in the early 2000s, busy failing to get on to the GB team pursuit squad, I spent quite a few nights in the squad house. It was the only still-occupied terrace in an otherwise boarded-up street behind the Velodrome, and was among the most frightening places I've ever been. If I'd been half as fast at the training sessions as I was at barrelling down the dark street afterwards, ramming the key into the lock, flinging myself through the door and locking it behind me, I'd have had a much brighter track career than I did. If I was staying there on my own I used to wedge the sofa behind the door as well, and sleep with a heavy frying pan beside the bed. As feral teenagers howled like wolves in the street outside it was a comfort to remind myself that I was involved with one of the best-funded cycling teams in the world.

One night I shared it with a group of juniors, which included Mark Cavendish. It was the night of the Champions' League final. I put it on the TV. We all watched it for a few minutes, until one of the lads said, 'Do you mind if we watch something else? We're not really into football.' I'd found the only group of 17- and 18-year-old males in the country with no interest whatever in football.

What happened next was even more interesting. One of them produced several VHS tapes of races. He put one on, fast-forwarded to a sprint finish, and together they analysed the hell out of it. They scanned backwards and forwards for what felt like hours till they'd worked out exactly, and I mean *exactly*, why the winner had won and the losers had lost. 'What happened to Zabel?' 'He should have swapped to that Saeco guy's wheel there, cos his lead-out got hit by the crosswind there from that gap in the buildings.' 'Nah, if he'd done that, the Festina guy would have shoved him into the barrier. He's already in trouble cos he's stuck behind the Gan guy, and the Gan guy is in the wrong gear...' and so on, forever and ever. It wasn't the conversation a group of fans have, or even a group of journalists. It was much more serious, much more knowledgeable. They were revising for their next race.

These were riders who knew they had some talent, who wanted to succeed, and who knew what that meant. There was no danger whatever of them going to the local supermarket and bringing back a few tins of lager. There wasn't even any danger of them going to the local chip shop. They knew they'd got a golden opportunity, and they were not going to waste it.

That group of riders would be in their late twenties by now. When a more recent under-23 international told me about a training session that consisted of short sprint reps performed in an altitude chamber, I asked what the idea behind it was. He shrugged and said, 'I don't know. I don't have to know – I have people to know this stuff for me.' I was left wondering if there was a younger generation that was a bit less engaged.

When I made the suggestion to a number of coaches, though, for the most part they disagreed. Paul Manning said that the single biggest change since he'd been a rider was the level of knowledge the younger riders had, having grown up through a much more advanced sport, one where there was more information and help available than there was when he was coming through. He was adamant that even the younger riders in his squad were well able to lead their own programmes.

I'm not sure there is really all that much of a contradiction. For the old guard – Hoy, Manning perhaps even Wiggins and, at a less-lavish pay-grade, me – the lack of sophistication in an old-fashioned-feeling sport enforced a degree of self-sufficiency. There simply wasn't the help available until you reached quite a high level, and until then you were probably on your own. Hoy's career was underpinned by a degree in applied sports science. I used to kill lunchtimes in the university library reading physiology journals. Even if I was usually holding the wrong end of half a dozen sticks at the same time, I was still better off than most.

Now the help is easier to find, and that has changed how riders develop. Dowsett said that I appreciated it as a 'knowledge base' that he could tap into. 'I've always had a team of some sort, British Cycling or a trade team, behind me so I haven't had to find things out on my own. I'm doing things that I know work. I have faith in them.' For that generation it's no longer a case of struggling to work things out for themselves, it's a case of taking on board what's there.

You could still ignore it all and just do what you're told. It's a lot more likely to work now than it was 20 years ago when the most readily available advice was either a magazine article or your mother. The former was hampered by its mandate to help everyone from the gifted 14-year-old to the middle-aged donkey without killing either, the latter by a perverse perception that your education ought to take priority over your bike riding.

In the end, the most successful riders seem to be those most closely involved in what they're doing. It means they can cope if things go wrong. It provides motivation. At its best, it's an attitude that goes beyond the day-to-day life of training. If you're a proper part of the process it makes what you're doing into a career rather than a job. It's telling that when Dame Sarah Storey switched sports from swimming to cycling, she made a conscious effort to be more fully in charge in her second sport: 'I've become something of a control freak. In the past, once or twice I allowed people to help me who didn't actually have my best interests at heart. There are ways in which you're just a number in someone else's big business model, and you can't just hand over your career, you need to know what decisions are being made. There are some younger athletes around the squad at the moment who are probably less involved in their own careers than they think they are.'

There's something else, of course. Everything I've said so far about being an athlete is limited in scope. I've talked about the bits where you're obviously on the payroll. The really difficult thing to deal with for many is this: everything you do will make you faster or make you slower. This isn't just everything you do from a training point of view, or even an eating point of view, but everything from an everything point of view. Because an athlete makes their living with their body, everything they do to or with it, everywhere they take it, and everything they put in it has some consequence. It might be an immeasurably small consequence, but there is nothing that is neither 'good' nor 'bad'. Marginal gain or marginal guilt – your choice.

All the time you ask yourself, 'Will it make me tired. Is there any risk I'll pick up an injury? Will I get an infection?' These are reasons to avoid standing up, walking, and staying awake. Or leaving the house for any purpose other than training.

I once went five years without going to the cinema. It wasn't that big a sacrifice – my body fat was sufficiently low that the lack of padding on my arse meant I couldn't sit still for long enough to watch a film all the way through anyway. I missed weddings – not just the ones I didn't want to go to (almost

all of them) but the handful I really wanted to be at. Only rarely was there a clash with an actual race normally it was just fear of getting a cold or giving myself tendonitis by dancing (very easy to do). When two of my best friends got married, the date of the wedding was planned to suit me. Not them.

In case you think it's just me that behaves like this, Chris Boardman missed the birth of his second child to go and recce the course for a national TT championships. Not actually ride the race anything. Just go and look at the roads. It was, I suppose, a question of priorities.

I didn't mind this sort of thing all that much. If you have the feeling that I'm not the sort of man who regrets too deeply being unable to spend his weekend evenings compacted into a pub full of shoulders and elbows so that I can shout 'no, really, just a still mineral water please' into a variety of badly cleaned ears, then you'd be right. There are riders for whom it's something they badly miss something that makes them unhappy and resentful.

This is when it gets complicated. Here's the equation: if I go out, there is a 5% risk I'll catch a cold and a 3% risk I'll get tendonitis. There is a 15% reduction in the effectiveness of my recovery from the previous day's session, and a 20% reduction in the commitment I'll be able to summon up for the following day. There is a 30% risk I'll fall off the wagon and get bladdered, whereupon I might well not have done most of the previous week at all. However, I'm also sick to the back teeth of living like a monk. If I don't have a night out, have a bit of a release, see some people who don't spend their whole lives worrying about their lactate thresholds and, what's worse, talking about it, there is a 50% risk I'll get so pissed off that all motivation will cease, and the quality of everything I do will enter a decline. There is a 3% risk that things will get so bad I'll either give up competitive cycling, or get fired by the team at the end of the season. Jesus, I need a drink.

I've heard one or two riders refer to the odd night out as 'morale training'. It's a good expression for it. It's got the word 'training' in it, so it's got to be a good idea.

That equation is not the end of it. The aim of a professional athlete is to reduce life to training, eating, and recovering – sitting about. The sitting about is deadly. At a training camp you can feel your life dribbling through your fingers. You can walk round the hotel and find riders in corners making endless Skype calls, playing video games, watching films, or just staring blankly into space waiting for the next excuse to get on a bike. I wrote my first book because of the sitting about. I think it was either that or learn the guitar, and I thought the book would annoy people less.

Stresses stack up, wherever they come from. The hormones involved create physical effects – so the boiler breaking down disrupts your recovery. The aim of a training camp is to eliminate all the bits of home life that might marginally get in the way. No cooking, no shopping, no bills to pay, no one round for dinner. No promises to keep. In an ideal world you'd eliminate everything from home as well. You'd regress to a second infancy, one with even less stress than the first one. Ride, eat, drowse your way through half a movie, and sleep.

It's hard to ride seriously and hold down a job, even where the job is essentially sedentary. You'd think being a writer would be ideal – I mean, it's basically indistinguishable from sitting about. It's better than most, but it's hard to be a good writer and a good athlete at the same time. The energy seems to come from the same place. I know several retired riders who've agreed that a normal day's work is exhausting. A lot of them abandon bike riding immediately the pay-cheques stop because they struggle to find the time and enthusiasm as soon as cycling has to fit round life rather than life fitting round cycling. Most, eventually, come back to it. Usually not long after they realise they can no longer see their feet.

I'm going to go out on a limb here, and make a suggestion that I have only anecdotal evidence to support. I think that for a lot of professional bike riders, there is a progression to their relationship with their sport. It starts when they are young, and they ride a bike, and they love it. They like riding

fast. They like swishing round corners. They like the feeling. They enter their first race, and most of them either win, or very nearly win, because almost nobody who's on the way to becoming an elite rider is a turkey first time out.

Competition becomes more important. A new world beckons, one of racing and training and looking for the small gains and worrying about the details. Websites and magazines are trawled with care. A coach appears, either sought out by a rider or their parents, or just as likely, the coach comes looking for the rider. The degree of seriousness takes another step up.

This is the point where it becomes about being an athlete, rather than about being a bike rider. They enjoy the process. The relationship with the coach, being part of a team. Watching themselves improve, developing a career. Competing. Winning. And most of all they enjoy having found something they are good at.

To go back to Dowsett for a moment. I interviewed him in a well-known cyclists' cafe in Essex one Wednesday morning. He'd ridden the hour over from home. The place was filled with Essex bike riders, many of them of a certain age, stopping to refuel on a ride. 'Something I don't often say, in the case people take it the wrong way,' said Dowsett, 'but look around. This place is full of people who just love riding, love getting out on their bikes for a few miles. Most pros aren't like that. There are a few, but not very many, and I'm not one of them. I don't enjoy the training very much. But I love racing. I love winning. Most of all, I've found something I'm very good at, and I very much enjoy being very good at it.'

It's dangerously easy to give the impression that the rarefied world of elite sport is a terrible place. 'It's hard.' 'It demands everything you have.' 'You give it your whole life – everything you do is part of your sport, part of your career.' 'You won't see the inside of a nightclub till you're so old that the music will have become that same indescribable racket your dad used to complain about every time you switched on Radio 1.' The things that are most easily articulated are those that make it all sound like a punishment, and my own accounts are more guilty of that than most.

The thing that no one talks about enough is the sheer pleasure of it. When I was at the height of my abilities, there were moments when the only way I could describe what it was like was to say I felt the way a thoroughbred horse looks at full gallop. There is a balance and a rhythm that is both irresistible and effortless. Like a galloping horse, every bit of you is part of the motion, even the bits that are quite still. The involvement, physically and mentally, is total, because you've trained all of you for this one task, and you've had the purity of purpose in your life to do it without compromise. Everything you've ever done comes to a single point. For a few moments you feel quite perfect.

Winning is nice. When you're a young athlete it's a thrill, when you're an old athlete it's a relief and it's no less wonderful for that. It can pay the bills. It can certainly justify your time and your career, because winning is the only negotiable currency in the world of sport. Winning reassures everyone that you are not wasting your life, it makes it clear that you are good at what you do. But winning isn't as much of a joy as that feeling of balance and rhythm. By the end of a career, winning will quite probably be something you can take or leave, because you'll have learned that winning isn't something you can control. It's the perfection you'll be desperate to feel one last time.

I'm aware there's an arrogance about what I'm saying, because I'm suggesting that sport at the elite level is different in its kind, not just in its speed. Perhaps it's not quite that black and white. But there is something about the dedication of whole years of existence to a single physical goal that I think does make it special. It's what you're for.

There are things that are less visceral. There is satisfaction in getting towards the top of any field. There is pleasure in both the collaboration of a team, and the solitary focus of an individual rider. There are days when, despite everything going wrong, you still manage to fight back for something that you can be proud of, even if it goes unnoticed by anyone else.

You can go for an easy recovery ride, one of the times you might take a moment to look at the hedges and the fields, and find yourself smiling at the idea that your recovery ride has become faster than you were once able to race. There is even something rather nice about the feeling of deep-down tiredness that swamps you after some hard races or training sessions. You can paste yourself to the sofa with the feeling, right there in your legs, of a job done well.

Parts of an athlete's life are hard, yes. But having the chance to dedicate yourself to something that's both so extraordinary and so unnecessary means it's also rather wonderful.

CHAPTER 2

Blood, oxygen and muscle: the physiology of an athlete

There is a story that at a British time trial event in the 1970s, one of the discipline's grand champions was asked by a well-beaten rival just what the secret was. Why was he so good? Why could he do what no one else could? Was it a training session no one else had stumbled upon? Was it a special way of pedalling? Was it psychological? There had to be ... something. Something that made him different.

The grand champion said he would show him. He led him over to his bike and pointed at one of the pedals. His rival bent down to give it a close examination. 'You see that? Well, when that little bastard gets to the top, I kick it to the bottom as hard as I'm able. When it gets to the top again, I do the same thing. And I keep doing it.'

This is pretty much the secret.

Cycling is a sport of details, of tactics, technology, training and psychology. But before it is any of those things, it is a sport that depends on how hard you can turn the pedals. This is the absolute basis. However obvious it might appear, almost everyone involved in cycling manages to forget it at some point.

Ours is a sport that is intensely physiological. There is not much technique, not really. The bike, the wheels, the helmet, they all make some difference. Maybe at the top level they make a significant difference. But zoom out to the big picture, and the details become just details and what matters is about force through the pedals. That's what distinguishes the stars from the also-rans, and the also-rans from those who didn't even make it to the race. Cycling may well be the most physical and unforgiving sport there is.

The fundamental differences between individuals can be pretty large. Sir Bradley Wiggins won the British ten-mile time-trial championships in 2011 – one of his relatively few appearances at a UK domestic race. I'm picking on this race because the field was not of big-name pros, but consisted of riders from Wiggins down to good domestic club riders – people with some talent who take the sport reasonably seriously but who aren't professionals, and certainly aren't global stars.

Wiggins won the event in 19'14". I was second in 19'55", which was less of an embarrassment than I was expecting, but that's not where I'm going with this. The rider in 93rd place did 24'03". For him to have ridden as fast as Wiggins would have required him to find something around twice the power he actually produced. Clearly there are some other issues around that – aerodynamics being the main one – but it's still a daunting margin. Ride as hard as you possibly can. You're halfway there.

If 93rd seems a bit too distant to be relevant, well, here's another way of looking at it. Wiggins

average power for the ride was about 470w. He could still have made the top 20 on 334w. For Wiggins, 334w is easy training pace. Given enough fuel, he could do it almost indefinitely. Five to six hours would certainly not be any kind of a problem, and he could do it while holding a conversation that was in no way compromised by having to breathe anywhere that there wasn't a comma. But it's still good enough to beat some relatively serious bike riders.

On the other hand, Wiggins, flat out in a sprint, would probably not manage any more than 1,200w (this is an educated guess – these aren't the kind of numbers that get handed out too readily). A track sprinter of the Sir Chris Hoy variety can hit something over 2,300w – not only that, but he can do it from a standing start, which Wiggins certainly couldn't. Hoy, in turn, would quite probably struggle to finish twentieth in the ten-mile championships. Neither could beat Mark Cavendish in a big bunch sprint on the road. And none of these three, not even Wiggins, would live with a full-blooded attack by a pure climber in the high mountains.

And all three are, in their own way, much, much finer examples of kicking the bastard pedal around than 99.99% of the rest of us.

Understanding how an athlete can do what they can do starts with their basic physiology. I want to ignore, for the moment, the issues of how they come to have that physiology in the first place, or how they would set about trying to change aspects of it that aren't as good as they might be. I'll get to that later. For now, I just want to look at exactly what an athlete is.

My first attempts to understand all of this came when I started working with the exercise physiologist Jamie Pringle. Ten years ago, he called me out of the blue one afternoon to see if there was any physiological support he could offer during an attempt I made on the world hour record. It says a lot about how much the sport has changed in the decade since that up till then I hadn't even thought to look for any scientific backup – indeed I didn't even have a coach at that point, having parted company with the GB squad coach who'd been looking after me up till then.

When Jamie tested me in the lab – an exhilarating world of stationary bikes, breathing masks, rubber gloves and blood samples – I was genuinely astonished at the results. Despite displaying a fairly clear talent for riding a bike, it hadn't occurred to me – or indeed to anyone else – that I was anything special. The first announcement of my abilities came from a machine, and frankly, being told you're brilliant is an experience that is only enhanced by that kind of objectivity.

The machine in question, merely the first of many adoring pieces of lab equipment to which Jamie introduced me, was one that measured lung capacity. You blew into a hose, and a pen drew a line on a bit of graph paper (it was an endearingly analogue machine). I blew the pen off the top of the graph in the most literal sense. I could tell that was unusual, because there were no other lines on the machine's plastic case. I managed to expel just under eight litres, which for someone of my height (180cm) is, in all modesty, phenomenal. I had a peak ventilation rate – just how much you can breathe in and out in a minute – of around 230 litres. As Jamie put it, I was in horse territory. If riding a bike didn't work out, I would clearly have a vocation as an assistant to a balloon-animal maker.³

The big-ticket number in these things is VO_2 max – a concept that has entered common parlance among those bike riders who tend even slightly towards the geeky. It's simply the maximum amount of oxygen you can use in a minute. You find it by means of a torture that consists of riding a stationary bike at a pace that increases relentlessly until eventually your body screams that it can't pedal no more and you collapse over the handlebars. While you're riding, a physiologist measures how much oxygen you're using via a mask and an expensive machine. The biggest number that flicks across the screen is your VO_2 max. You can keep going, and ride faster than VO_2 max pace – albeit not for all that long – but you won't be able to use any more oxygen to do so. It's your maximum

aerobic capacity, or the size of your aerobic motor, in millilitres of oxygen per minute per kilo of body weight. Think of it like the cubic capacity of a car engine.

An average untrained man of my age would have a VO_2 max of around 40ml/m/kg. Training effects vary by individual, but an average for a decent club athlete would be something like 60. I hit 85. A year later I hit 90, which was higher than any other cyclist any of us had ever heard of. There have been a handful who've topped that since, but you could probably count them on your fingers.

(It's worth saying that reliable numbers are sometimes difficult to find because physiologic studies of professional sportsmen have been badly corrupted over the years by the doping problem. Some numbers may be trustworthy, some certainly aren't. The numbers provided for Lance Armstrong were widely agreed to be implausible because they were too modest. He simply wouldn't have been able to go as fast as he did if the study numbers were all he'd been able to do. If you took the lab results at face value, I should have been faster than him. Somewhere between the lab and the road he apparently found a second heart and some extra blood. Which was at least half true.)

I didn't really know what to make of all this. In a basic way it answered the question of why I was so fast on a bike: I had a very big engine. But, if you're at all inquisitive, that was where a lot more questions began. What was the key to it? Was it just lung capacity? Or was it more complicated?

But there was a more pressing question. If I was that good in the lab, why was I not a much better bike rider in the real world than I actually was? And was knowing more detail about how I functioned going to lead me to something I could do that would reduce that discrepancy?

There are no simple answers to any of this. Human physiology is so complicated that I find myself regularly regarding it as a proof against the theory of intelligent design, on the basis that absolutely no one would have set about designing something that was so convoluted, contradictory, and just plain messy. Like a taxation system, it swirls with bits apparently slapped on at random to fix a loophole that no one saw coming, with widely differing solutions to apparently similar problems deployed according to no criteria that are obvious. It is chaos in there. How we've made sense of what we've learned so far baffles me, and there is plenty of weirdness left to go.

The scale of the differences between individuals are perhaps most astonishing of all. For anyone who's interested in physiology in elite sport and wants to push performance forward, it's the variances that are important. The average abilities of a large population are interesting, but other than giving you a basic benchmark, or a warm glow of unearned superiority, they're of little help.

Even the averages of an elite group of athletes in the same sport don't tell you all that much. What you really want to know is not that an athlete is extraordinary, but exactly how they're extraordinary because there are quite a few different ways to excel at the same thing. VO_2 max is great as a single figure guide, especially for physiologists, because it's quite stable from day to day – it doesn't depend on how hard an athlete tries. But in the real world, its usefulness is diminished by a host of other variables. If you want to perform better, you need to know precisely what's holding you back, and that's not necessarily the same thing that's holding someone else back.

Let's slip away from bike riding for a moment, and into marathon running, which as a sport is approaching the headline-breakthrough of the sub-two-hour run. (I'm using it because it's the kind of objective record that cycling generally lacks.) To do it would take a runner with a VO_2 max of about 92ml/m/kg, with the ability to run at about 85% of that effort level for the race. They'd also need to be highly efficient in the way they combine that oxygen with fuel and turn it into forward motion, around 180ml/kg for every kilometre covered. To extend the earlier car-engine metaphor, this means that the athlete would have to have a large capacity, the ability to run for two hours at almost maximum revs, and to produce power efficiently.

These numbers are not impossible, or even extremely rare. In the UK alone there are several runners

with one of these characteristics, and a few with two. No one in the world has yet managed to combine all three.

As a road time-trial rider, my concerns were very similar to those of a marathon runner. It was all about endurance physiology and aerobic conditioning. The issue of sprint physiology, anaerobic energy, was still an element of what I was doing, but a sufficiently marginal one that it was never where I went looking for gains. My career was unusually pure: most competitive bike riding involves a much more flexible combination of aerobic and anaerobic. On the road, attacks and sprints have an anaerobic component, as do short prologues and team time trials. All track events have at least some element of sprinting to them. But I'm going to start with what I'm good at, and that's moving around using oxygen.

I'm going to attempt to explain what goes on during exercise via a practical demonstration. There are a number of standard lab-test protocols to which physiologists enjoy subjecting athletes. The second least pleasant of these is called a ramp test – we'll get to the least pleasant one a little later. The details are from a test I did a few seasons ago, selected more or less at random from a year when both Jamie and I were trying to keep a close track of the changes to my physiology over the course of a racing season, and consequently did a lot of lab work. I also admit that, from an ego-massage point of view, it's one of my better tests.

The protocol was a simple one. I started pedalling on a stationary bike at a power output of 200w. Every 15 seconds, the power required edged up by five watts. This happened automatically. This ramp continued until I was no longer able to keep going – the point of failure or exhaustion. Throughout, my pulse was recorded and my expired breath went to a gas-analysis machine that kept track of what I was breathing out, and hence what was happening to the air in my lungs. Every minute a blood sample was taken from my thumb, and analysed for lactate concentration. You may know lactate better as 'lactic acid' – it's produced in the muscles, especially during intense exercise, and its concentration in the blood is used to define some important landmarks. It's measured in millimoles per millilitre. That's the closest to biochemistry we're going to get. There's no need at all to know what it means, but we have to call it something.

The ramp-test starting point of 200w is dead easy – for me it was below even recovery pace. The only thing stopping me from trying to continue a conversation was the breathing mask. My pulse at that point was just under 120bpm – beats per minute – equivalent to not much more than walking. I was using 2.4 litres of oxygen a minute. The lactate level was 1.1mmol/ml, actually slightly lower than my resting lactate level.

Five minutes later, at 300w, all that had moved on to a pulse of 142bpm, oxygen uptake to 3.5 litres a minute and lactate remained at a constant 1.1mmol/ml. 300w is still pretty easy – at that point in the season it was less than my long ride (four- to five-hour) average.

Here, roughly, is what's happening. Each breath takes air to the lungs. You don't replace the whole contents of your lungs with each breath, so the air there has less oxygen than fresh air – in the depth of the lung it's about 14.5% oxygen compared to 20.1% for the air outside, with carbon dioxide accounting for the difference.

Oxygen diffuses into the blood simply because (even at 14.5%) it is more concentrated in the air in the lung than it is in the blood – it's pushed by a pressure gradient. Carbon dioxide diffuses in the opposite direction, again because of the difference in concentration. The exchange of gases is very very fast – it takes about a quarter of a second to complete. At rest, that's about a third of the time it takes the blood to pass through the lungs. Even if you're racing at full stretch, it doesn't change very much because the blood vessels transiting the lung increase in volume to allow a higher throughput of blood without much increase in its actual speed. Blood will take as much oxygen as it can hold from

the normal concentration of oxygen in the lungs – you wouldn't get any more by breathing pure oxygen.

Contrary to what you might expect, a very great deal of endurance ability is not in the lungs, or the muscles, but in the blood. How much oxygen the blood can move round the body is critical. Just how critical you can judge from the phenomenal amount of time, money, inconvenience, risk, drug-testing, dodging and generalised dishonesty that has gone into illicitly improving it over the last couple of decades. There are two main issues: the quantity of oxygen a given amount of blood can carry, and how much blood you have in total.

The first question depends on the amount of haemoglobin you've got, since that's what carries the oxygen, and that depends on the number of red blood cells you have. If you use a centrifuge to separate out the different elements of blood, you find that the average for a given quantity of ordinary non-athletic blood is about 46% red cells for men and 40% for women. This percentage is called the haematocrit.

The variation is quite large – for men 42 to 52% would be unremarkable. But in endurance athletes it's a few percentage points less, because endurance training alters the composition of the blood. Most non-sprint riders have the rather dramatically titled, but basically harmless, condition of athletic anaemia: their blood is diluted by a greater than normal amount of plasma, the liquid in which all the cells bob about. The increase in plasma occurs within a few days of starting regular training, and can be quite large.

The changes don't end there. Over the next three to four weeks of training the total number of red cells will rise as well, though it doesn't usually match the increase in plasma. The eventual result is a greater amount of slightly less concentrated blood, but with a net increase in the total number of red cells. Since more blood is good, and more red cells are even better, the overall effect is that more oxygen can be carried. Blood plasma will also fall very fast when you stop training. It's the reason for most of the drop off you see, especially the increase in pulse at any given level of effort after a couple of weeks' break from training. And the rapid increase back to 'athlete-normal' plasma volume is why the first session back after a short break will be horrendous, the second will be bad, and the third will be almost the same as before the break.

There were riders in the 1980s and 1990s who took the process a very major step beyond what they'd get by mere training, and illegally boosted their haematocrit from what you'd expect at around 42–44% to over 60%, and in one particularly outstanding example 73%, either by using EPO to stimulate red-cell production or by simply infusing red cells. The relationship between red-cell count and carrying oxygen is a pretty direct one. One study found that an increase in haematocrit from 43% to 54% produced a huge 13% increase in VO_2 max. Blood doping is not something that makes some sort of footling, marginal difference to performance. It's taking your body back to the shop and exchanging it for a much, much better one. It's far beyond anything you could achieve with better training.

EPO is actually a naturally occurring hormone, which stimulates the production of red blood cells. Until the last decade it was impossible to distinguish the synthetic drug version from the natural version, and it's still not easy. The authorities' only recourse was a sort of clampdown that comprised taking blood samples from riders, testing them and making sure they didn't surpass a specific maximum haematocrit of 50%.

This was described as a 'health measure', because very high red-cell content made the blood thick and strawberry-jam-esque, and very hard for the heart to pump. Every so often an athlete would die from a mysterious heart failure, generally at night when the blood flow was slow. There were stories in the 1990s of athletes getting up in the middle of the night to jog up and down hotel corridors to get the blood moving a bit.

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