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About the Author

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Introduction: TEN

Is there a secret formula for becoming rich? Or for happiness? Or for becoming popular? Or for self-confidence and good judgement?

If you are browsing in your local bookshop and have picked up this book, or if you have just clicked on the 'Look inside' button in an online bookstore, then you will be aware that this is just one of many titles that offer you a formula for success in life.

Marie Kondo telling you to tidy up. Sheryl Sandberg telling you to lean in. Jordan Peterson telling you to stand up straight. Brené Brown encouraging you to be vulnerable. You are told you should calm the f*ck down, stop doing that sh!t, not give a f*ck, not be a miserable f*ck and make the most of your holy sh!t moment. You should get up early, make your bed, clear the path, do less, memorize more, declutter your mind, get things done, maximize your willpower, 'solve for happy', 'act like a lady and think like a man'. There are formulas for love, a science behind getting rich, a blueprint for success and five (or eight or twelve) rules for self-confidence. There is even, apparently, a miracle equation that claims to 'make impossible goals inevitable'.

All this advice presents a paradox. If it is all so simple, if there are seemingly easy formulas for getting everything we want from life, then why are all these books and lifestyle magazines full of tips with often contradictory messages? Why are there so many inspirational TV shows and TED talks offering motivational monologues? Why not just state the equations, give a few examples of how they work, and close down the self-help and smart-thinking industry? If it is all so mathematical, all so axiomatic, why not just tell us the answer – now?

As the number of suggested solutions to life's dilemmas increases, it becomes more and more difficult to believe that there is just one, or even a small number, of formulas for success. Maybe

there really is no simple remedy to all the problems that life throws at us?

I want you to think about another possibility, one that this book explores. I am going to tell you a story about an exclusive society of individuals who have cracked the code. They have discovered a small number of equations – ten of them in fact – that can bring them success, popularity, wealth, self-confidence and good judgement. It is they who hold the secret, while everyone else continues to search for the answers.

This secret society has been with us for centuries. Its members have passed their knowledge down through the generations. They have taken positions of power in public service, in finance, in academia and, most recently, inside tech companies. They live among us, invisibly but powerfully advising us, and sometimes controlling us. They are rich, happy and self-assured. They have discovered the secrets that the rest of us so desire.

In Dan Brown's book *The Da Vinci Code*, cryptographer Sophie Neveu discovers a mathematical code while investigating the murder of her grandfather. She is led to Professor Robert Langdon, who reveals that her grandfather was head of a secret society, the Priory of Sion, which understands the world through a single number, the Golden Ratio, $\varphi \approx 1.618$.

The Da Vinci Code is fiction, but the secret society I have investigated for this book has many similarities to the one described by Brown. Its secrets are written in a code that few fully comprehend and its members communicate in arcane scripts. The society has its roots in Christianity, and it has been torn by internal moral battles and conflicts. But it also, as we will soon find out, differs in important ways from the Priory of Sion. Unlike that society, it has no rituals whatsoever. This makes it far more difficult to detect and much more pervasive in its activities. It is invisible to those on the outside.

How, then, do I know about it? The answer to that is simple. I'm a member. I have been involved in its workings for twenty years and have gravitated closer and closer to its inner circle. I have studied the society's works and put its equations into practice. I have experienced at first hand the success that access to its code can bring. I have worked at the world's leading universities and was appointed full professor in applied mathematics the day

before my thirty-third birthday. I have solved scientific problems in fields ranging from ecology and biology to political science and sociology. I have been a consultant to those inside government, finance, artificial intelligence, sports and gambling. And I'm happy – partly as a result of my success, but mainly, I believe, because of how the secrets I have learnt have shaped my own thinking. The equations have made me a better person: more balanced in my outlook and better able to understand the actions of others.

Membership of this club has brought me into contact with others like me. People like Marius and Jan, young professional gamblers who have found an edge on the Asian betting markets; those like Mark whose micro-second calculations skim profits from small inefficiencies in share prices. I have worked with the data scientists at the football club Barcelona who study how Lionel Messi and company control the field of play. I have met the technical experts employed by Google, Facebook, Snapchat and Cambridge Analytica, who control our social media and are building our future artificial intelligence. I have witnessed at first hand how researchers like Moa Bursell, Nicole Nisbett and Viktoria Spaiser use equations to detect discrimination, understand our political debates and make the world a better place. I have learnt from the older generation, like ninety-four-year-old Oxford professor Sir David Cox, who have discovered the code on which the secret society is built.

Now I am ready to name the secret society to which I and they belong. I will refer to it as 'TEN ', based on the number of equations a fully qualified member needs to know. I am ready to reveal its secrets – to tell you the Ten Equations.

The problems TEN addresses include everyday dilemmas. Should you quit your job (or your relationship) and try something else? Why do you feel that you are less popular than those around you? How much effort should you put into becoming more popular? How can you best cope with the vast flood of information from social media? Should you let your kids spend six hours a day staring at their phones? How many episodes of a Netflix series should you watch before trying something else?

These might not be the problems you expect a secret society to be resolving. But here's the thing. The same small set of formulas can provide the answers to questions ranging from the trivial to

the profound; and about you as an individual and society as a whole. The confidence equation, introduced in Chapter 3, which helps you decide whether you should quit your job, also allows professional gamblers to know when they have an edge on the betting markets and reveals subtle racial and gender biases at work. The reward equation, discussed in Chapter 8, shows how social media has driven society to tipping point and why this isn't necessarily a bad thing. By understanding how this and other equations are used by Internet giants to reward us, to influence us and to classify us, we can better balance our own and our children's use of social media, games and advertising.

We know these equations are important because of the success they have brought the people who already use them. Chapter 9 tells the story of three engineers in California who used the learning equation to increase the time viewers spent watching YouTube by 2,000%. The betting equation, the influencer equation, the market equation and the advertising equation have reshaped, respectively, betting, technology, finance and advertising to generate billions of dollars of profits for a small number of TEN's members.

As you learn the equations in this book, more and more aspects of the world will start to make sense. When you see through the eyes of TEN, big problems become small and small problems become trivial.

If you are just looking for quick fixes, then there is, of course, a catch. To be admitted to TEN you will need to learn a new way of thinking. TEN asks you to break down the world into three categories: *data*, *model* and *nonsense*.

One of the reasons TEN is so powerful today is that we have more *data* than ever: movements of the stock exchange and betting markets; and personal data about what we like, buy and do collected by Facebook and Instagram. Government agencies have data on where we live, how we work, where our children go to school and how much we earn. Pollsters collect and synthesize our political views and attitudes. News and opinions are collated on Twitter, in blogs and news websites. Every movement of sports stars on the field of play is logged and stored.

This explosion of data is obvious to everyone, but TEN's members have recognized the importance of identifying

mathematical *models* to explain the data. Like them, you can learn how to build models, to use the equations to take control of and use data in a way that gives you an edge, a small advantage, over others.

The final category, *nonsense*, is something we need to learn to spot. You will come to understand that, as enjoyable and fulfilling as it can be to talk nonsense, and while we all do it a lot of the time, you will need to put it aside when you think like a member of TEN. We need to call out nonsense whenever we encounter it, no matter who voices it. I will show you how to ignore nonsense, and refocus on data and model.

This is not just a self-help book. It is not the Ten Commandments. It is not a list of dos and don'ts. There are equations in this book, but no recipes. You can't simply skip to page 157 and find out the exact number of Netflix episodes you need to watch.

Rules and recipes exploit our fears. Instead of building on those fears, this book explains how the code of TEN has evolved over and shaped the last 250 years of human history. We are going to learn from the mathematicians who developed the code and understand the philosophy that underlies their thinking. Learning TEN challenges many of our everyday assumptions. It involves rethinking terms such as 'political correctness', re-evaluating the judgements we make about others and reconsidering the stereotypes we create.

This is also a tale about morality, because it would be wrong of me to reveal so many secrets without investigating the effect the society of TEN has had on the world. If a small group of people can steer the rest of us, then we need to know what motivates the choices they have made. The story I tell here has forced me to re-evaluate myself and what I do. It has forced me to ask myself whether TEN is good or evil, and to think about the moral rules we should set up for ourselves in the future.

When handing down his power to a new generation, Spider-Man's uncle tells him that 'with great power comes great responsibility'. With so much at stake, the hidden powers of TEN require even greater responsibility than those bestowed by a Spider-Man suit. You are about to learn secrets that can transform

your life. And you will also be forced to think about the effect these secrets have had on the world we live in.

For too long, the code has only been accessible to a chosen few. Now we are going to talk about it, openly and together.

1

The Betting Equation

The thing that first struck me about Jan and Marius as we shook hands in a hotel lobby was that they were not much older than the students I teach at university. And here I was, hoping to learn as much from them about the world of gambling as they presumably hoped to learn from me about maths.

We had chatted online, but this was the first time we had met in person. They had flown in to see me as part of a kind of European tour, meeting football betting experts and tipsters one by one to prepare their own strategy for the coming year. My hometown of Uppsala, Sweden, was their final stop.

'Shall we take our laptops with us to the pub?' Marius asked me as we prepared to leave the hotel.

'Of course,' I replied.

This may well have been a 'getting to know each other' meeting, before we started work properly the next day, but all three of us knew that even the most informal of discussions would require some number-crunching. The laptops always had to be on standby.

You might think that successful football gambling requires a lot of knowledge; that you need to have an in-depth understanding of the game, including knowing the form of each of the players, having some insight into injuries and perhaps getting your hands on some insider information. A decade ago, that might well have been the case. At that time, carefully watching the matches,

observing the players' body language and seeing how they performed in one-to-one situations might have given you an edge over the punters who naively backed the home favourite. But not any more.

Jan had only a cursory interest in football and he had little intention of watching the majority of matches we were going to bet on in the upcoming 2018 World Cup. 'I'll enjoy the Germany matches,' he said with a confident smile.

It was the evening of the opening ceremony, the start of an event that few people on the planet, with or without an interest in football, could avoid hearing about. But aside from Jan's interest in his own national team, to him it was all the same – Bundesliga, Norwegian Tippeligaen or the World Cup; tennis or horses. Each tournament and each sport was just another opportunity for him and Marius to make money. And it was their search for these opportunities that had brought them to me.

A few months earlier I had published an article about my own football betting model.[1] This was no ordinary mathematical model. At the start of the 2015–16 Premier League season, I wrote down a single equation and proposed that it could beat the bookmakers' odds for Premier League match outcomes. It did.

By May 2018 it had racked up a 1,900% profit. If you had invested £100 in my model in August 2015, then less than three years later you would have £2,000. All you would have had to do was unthinkingly place the bets my model suggested.

My equation had nothing to do with what happened on the pitch. It certainly didn't involve watching the matches and it definitely didn't care who won the World Cup. It was a mathematical function that took in the bookmaker's odds, adjusted them slightly for a historical bias, and suggested new odds on which to bet. That was all that was needed to win money.

I had been completely open about my equation and it had garnered quite a bit of attention. I had published the details in *The Economist*'s *1843* lifestyle magazine and had talked about it in interviews with the BBC, CNBC, with newspapers and on social media. It was hardly a secret. It was this model that Jan and Marius were asking me about now.

'Why do you think you still have an edge?' asked Marius.

The currency of gambling is information. If you know something that other people don't know and that piece of information makes money, then the last thing you want to do is share it. The term 'edge' refers to that small informational advantage you have over the bookmakers. In order to protect your edge, you should keep it a secret. If the money-making scheme gets out, then others will exploit it and the bookmakers will correct their odds. Your edge will disappear. That is the theory, anyway. But I had done the opposite. I had done everything possible to tell people about my equation. Marius was wondering why, despite the publicity, my model still worked.

A large part of the answer to Marius's question can be found by scrolling through the emails and DMs I get every day asking for betting tips: 'Who do you think is going to win tomorrow's match? Read a lot about you and started believing in you'; 'I intend to raise funds to help me build capital to start a business. Your football tips would definitely lead me in the right direction'; 'Who have you got – Croatia or Denmark? I have a gut feeling Denmark will pull it off, but I'm not too sure'; 'What do u think the result gonna be in the England match? draw?' The requests go on and on.

I don't feel particularly good about saying this, but the reason that people keep sending me these messages also answers Marius's question. Despite my efforts to outline the limitations of my approach and my emphasis on a long-term strategy based on statistics, the public's response consisted largely of messages asking things like ' Will Arsenal win at the weekend?' or 'Will Egypt qualify from the group-stage if Salah doesn't play?'

It gets worse. The people who email me have at least searched the Internet for maths and gambling advice. There are many more who gamble without doing any research. They are gambling on a gut feeling, gambling for fun, gambling because they are drunk, gambling because they need cash and (in some desperate cases) gambling because they can't stop themselves. And, in total, there are many more of them than the small group of informed gamblers who are using my method or something similar.

'The reason the model continues to win is that it suggests bets people don't want to make,' I explained to Marius. 'Betting on a draw when Liverpool play at Chelsea or backing Manchester City

to beat Huddersfield at small odds isn't fun.' It takes time and patience to make a profit.

Marius's first email to me fell into the 1% of messages that are different. He told me about an automated system that he and Jan had developed to find value in betting markets. Their idea was to exploit the fact that the majority of bookmakers are ' soft ', that they offer odds that don 't always reflect the true probability of a team winning.

The vast majority of punters (most likely including all those who were sending me messages asking for match tips) use 'soft' bookmakers. High street names like Paddy Power, Ladbrokes and William Hill are soft, as are smaller online names, such as RedBet and 888sport. These bookmakers prioritize special offers to encourage customers to gamble, but pay less attention to creating odds that reflect the probable outcome of sporting events. This latter activity, of accurately tuning odds to predict match outcomes, is performed by 'sharp' bookmakers such as Pinnacle or Matchbook, which are typically used by the other 1% of gamblers.

Marius and Jan's idea was to use the 'sharp' bookmakers to cream money from the 'soft' bookmakers. Their system monitored the odds at all bookmakers, soft and sharp, and looked for discrepancies. If one of the soft bookmakers was offering more generous odds than the sharp ones, then their system would suggest a bet at that particular soft bookmaker. This strategy by no means guaranteed a win, but since sharp bookmakers were more accurate, it gave Jan and Marius their all-important edge. In the long term, over hundreds of bets, they would win money at the soft bookmakers.

There was one limitation to Jan and Marius's system: the 'soft' bookmakers ban winners. It is the bookmakers who decide if they want your custom, and as soon as they saw that Jan and Marius's accounts were making a profit, they would ban them. 'You are now restricted to a maximum bet size of £2.50,' the message from the bookmakers would read.

But the guys had found a way to get their own back. Having developed their system, they were now offering a subscription service. For a monthly fee, subscribers were alerted via a direct link to value-for-money bets at soft bookmakers. This meant that Jan and Marius could continue to profit even if they themselves

got banned. It was win-win for all involved, apart from the bookmakers. Part-time gamblers could get tips that would win in the long term, and Jan and Marius took a cut.

This was why I was sitting here in the pub with the two of them. They had mastered the art of gathering data and placing bets automatically. I had developed an equation that could further improve their edge: my model of the Premier League could not only beat the soft bookmakers, but also the sharp ones.

At this point I believed that I'd found an edge in the upcoming World Cup. But I needed more data to test my hypothesis. Before I finished telling them about my idea, Jan had his laptop open and was trying to get on the pub Wi-Fi. 'I'm sure I can get the qualifying odds and the odds from the last eight major international tournaments,' he said, 'I've got some code that will scrape [the term for automatically scanning web pages and downloading data] them for us.'

By the time we'd finished our drinks we had a plan and had identified the data we needed to carry it out. Jan went back to his hotel and set up his computer to scrape historical odds overnight.

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Both Jan and Marius are of a new breed of professional gambler. They can programme a computer, they know how to get hold of data and they understand maths. Their type is often less interested in a particular sport and more interested in the numbers than the old-school gamblers. But they are just as interested in making money and are much better at it.

The betting edges which I had uncovered had put me on the pair's radar and let me into the peripheries of their gambling network. But from the cautious answers they gave at the pub when I asked about other projects they were working on, I could tell that full membership to their club wasn't on offer. Not yet, anyway. I was an amateur – they had laughed at me when I said I planned to place £50 bets on the system we were developing – and information about their other projects was shared on a need-to-know basis.

I had another contact, though, who had already been more open with me. He had recently left the sports trading industry, and

while he didn't want me to reveal his identity and who he had worked for – we'll call him James – he was happy to share his experiences.

'If you have got a genuine edge, then the only limit to how fast you can make money is how quickly you can place bets,' James told me.

To understand James's point, first imagine a traditional investment with a 3% rate of return. If you invest a total capital of £1,000, then one year later you will have £1,030, a profit of £30.

Now consider gambling with £1,000 and an edge of 3% over the bookmakers. You certainly don't want to risk all your capital on one bet. So, let's start with a bet of £10, a relatively modest risk. You won't win every bet, but a 3% edge means that, on average, you will win 30p per bet on a £10 stake. The rate of return on your £1,000 investment is thus 0.03% per bet.

To expect to make a profit of £30 you will need to place one hundred £10 bets. One hundred bets per year, or roughly two per week, is more than most of us would place. For us amateurs, it is sobering to understand that, even if you do have an edge, as a casual gambler you can't expect to make much from a £1,000 capital investment.

The guys that James worked with weren't casual gamblers. Across the world, there are easily 100 football matches per day. Jan had recently downloaded data for 1,085 different leagues. Add to that tennis, rugby, horses and every other sport under the sun and there are a lot of betting opportunities out there.

Let's imagine for now that James and his colleagues just have an edge on football, and bet on those 100 matches per day throughout the year. Let's also assume, as the profits roll in, that they increase their stake size in proportion to their bankroll, so once they have made £10,000 they stake £100 on each bet. At £100,000 the stakes are £1,000 and so on. How much will gamblers with a 3% edge have made by the end of the year? £1,300, £3,000, £13,000 or £310,000?

By the end of the year they should have £56,860,593.80. Nearly £57 million! Each bet multiplies the capital by only 1.0003, but after 36,500 bets the power of exponential growth kicks in and the profits multiply dramatically.[2]

In practice, however, this level of growth isn't achievable. Even if the sharp bookmakers used by James and his former colleagues

allow larger bets than soft bookmakers, there are still limits. 'The betting companies in London have grown so quickly and become so huge that they have to place their bets through brokers now. Otherwise, if it becomes widely known that they are placing a certain bet on a certain match, then everyone else floods into the market and their edge disappears,' James told me.

Despite these limitations, the money is still flowing into equation-driven betting companies. You don't need to look any further than the stylish interiors of their London offices to see the evidence of their success. The employees of one of the industry leaders, Football Radar, start the day with a free breakfast, enjoy access to a luxury gym, can take a break to play table tennis or PlayStation and are provided with all the computer equipment they need and want. The data scientists and software developers are encouraged to work their own hours and the company claims to provide the type of creative environment usually associated with Google or Facebook.

Football Radar's two big competitors, Smartodds and Starlizard, are also based in London. These companies are owned by, respectively, Matthew Benham and Tony Bloom, whose careers have progressed through their skill with numbers. Benham studied at Oxford, where he started his statistics-based gambling operation, while Bloom has a background as a professional poker player. In 2009 both of them bought the football clubs of their home towns, with Bloom buying Brighton & Hove Albion and Benham buying Brentford FC. Once Benham had established himself as consistently ahead of the game, he decided it was best to own the game too, and added sharp bookmakers, Matchbook, to his assets.

Benham and Bloom both found small edges using big data and made massive profits.

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The edge that I proposed to Jan and Marius for the probability that the favourite wins a World Cup match is based on the following equation:

(Equation 1)

where x is the bookmaker's odds of the favourite winning. Here the odds are given in UK format, so that odds of 3 to 2 or $x = 3/2$ means that for every £2 staked £3 will be paid out if the bet is won.

Let's break down what Equation 1 actually says. We start with the left-hand side where I have written 'P(favourite wins)'. A mathematical model never predicts 'win' or 'lose' with absolute certainty. Instead, 'P(favourite wins)', the probability that the favourite wins, is a value between 0% and 100% predicting the level of certainty I assign to the outcome.

This probability depends on what we put into the right-hand side of the equation, which contains three letters, x from the Latin alphabet, α and β from the Greek. A student once told me that she thought that maths was straightforward when it came to dealing with xs and ys in the Latin alphabet, but that it got difficult when we started talking about αs and βs in the Greek. To mathematicians this is funny because x, α and β are just symbols, they don't make the maths more or less difficult, and I think the student was joking. But at the same time she made an important point: when α and β appear in equations the maths itself tends to be more difficult.

So, let's start without them. The equation

is much easier to understand. If, for example, the odds were 3/2 (2.5 in European odds, +150 in US odds) then the probability that the favourite wins is

In fact, this equation, without the α and β, tells us the bookmaker's estimate of a win for the favourite. They believe that the favourite has a 2/5 or 40% chance of winning the match. In the other 60% of cases, the match will end either in a draw or with the underdog winning.

Without the α and β (or strictly speaking with $\alpha = 1$ and $\beta = 1$) my betting equation is relatively straightforward to understand. But without the α and β this equation will not make any money. To see

why, think about what would happen if you bet £1 on the favourite. If the bookmaker's odds are correct, then you will win £1.50 two times out of five and you will lose one dollar three times out of five. On average you can expect to win

In words, the equation tells you that you should expect, on average, after lots of betting, to win nothing. Zero. Zilch. Except it is much worse than that. At the start I assumed the odds offered by the bookmakers were fair.[3] In reality, they aren't fair at all. The bookmakers always adjust their odds in order to tip things in their favour. So instead of offering 3/2, they will offer 7/5, for example. It is this adjustment that ensures that, unless you know what you are doing, they will always win and you will always lose. With 7/5 odds you will lose, on average, 4 cents per bet.[4]

The only way to beat the bookmakers is to look at the numbers, and this data was exactly what Jan's computer had spent the evening scraping together after we had left the pub. It had collected odds and results for every World Cup and Euros match, including qualifiers, since the tournament in Germany in 2006. In the morning, sitting in my office at the university, we started looking for an edge.

We first loaded the data and looked at it inside a spreadsheet like the one below.

Favourite	Underdog	Odds for favourite wins (x)	Bookmakers' probability favourite wins $\frac{1}{1+x}$	Favourite won? ('yes' = 1, 'no' = 0)
Spain	Australia	11/30	73%	1 (win)
England	Uruguay	19/20	51%	0 (lost)
Switzerland	Honduras	13/25	66%	1 (win)
Italy	Costa Rica	3/5	63%	0 (lost)
. . .				

Here we can see that what hardened gamblers call a long-shot bias exists against strong favourites, like Spain. These teams were typically under-estimated by the bookmakers' odds and therefore worth backing. On the other hand, weaker favourites like England were over-estimated in 2014. The chance of England winning was lower than suggested by the odds. Although these differences between predictions and model were small, Jan, Marius and I knew that they were big enough for us to make a profit.

We had found a small edge on the World Cup. What we didn't know yet was whether the edge in previous tournaments would be present this time around. But we were prepared to risk a bit of money to find out. It took until lunchtime to implement a trading system based on my equation. We pressed 'Run' and put it into action. Our bets would be placed automatically throughout the World Cup.

After lunch, we went back to my house. Marius and I sat in my basement and watched Uruguay play Egypt. Jan took out his laptop and started to download tennis odds.

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The betting equation isn't just about one World Cup, nor is it just about making money at the bookmakers. Its real power comes from the way it forces us to see the future in terms of probabilities and outcomes. Utilizing the betting equation means leaving our hunches behind and forgetting the idea that the outcome of a football match, a horse race, a financial investment, a job interview or even a romantic date can be predicted with 100% certainty: you can't know for sure what is going to happen.

Most of us have a vague idea that events in the future are, to a large degree, determined by chance. If a weather forecast tells you that there is a 75% chance it will be sunny tomorrow, then you shouldn't be too surprised if you find yourself caught in a downpour on your way to work. But finding the small edges hidden within probabilities requires a step up in your understanding.

If a particular outcome is important to you, then think about the probability that it will work out and the probability that it won't. I recently talked to a CEO of a very successful start-up that had

grown through four rounds of multimillion-dollar investment and had one hundred employees, and he happily admitted that the chance of long-term profit for himself and his investors was still only around 1 in 10. He was working long hours and was fully committed, while simultaneously aware that everything could suddenly unravel.

When looking for the job of our dreams or the love of our life, success rates for individual applications or dates can be very low. There are always factors outside your control. I am often surprised by the way people who fail at the interview stage for a job beat themselves up about what *they* might have done wrong, rather than consider the fact that this was very likely the day when one of the other four applicants did everything right. Try to remember that 20% success probability you had before you walked into the building for your interview. Until you fail five or so interviews, there is little reason to get down about any particular outcome.[5]

Romance is trickier to quantify, but the same probabilistic principles apply. Don't expect Prince or Princess Charming to turn up on your first Tinder date, although do take some time to reflect over your approach when you are sitting alone after unsuccessful date number thirty-four.

Once you have identified the probabilities involved, think about how they relate to the size of the investment made and the potential profits. My advice to think probabilistically is not a call for karmic calmness or an attempt to get you to be more mindful. The CEO with a 1 in 10 chance of success had a business idea that had the potential to be the next Uber or the next Airbnb – an idea that could build a 10 billion-dollar company. Ten billion divided by ten is still one billion, a massive expected profit.

Thinking probabilistically is about being realistic in the face of odds that are often stacked against you. In horse-racing and football, long shots tend to be overvalued by naive gamblers, but in real life we tend to undervalue long shots. We are cautious and risk-averse by nature. Remember that the pay-off of getting a job you really enjoy or finding a partner you love is massive. This means that you need to be prepared to take big risks to achieve your goals.

Maths requires hard work and perseverance. Five minutes ago, I finished reading one of the most remarkable papers in the history of applied mathematics, an article that is literally worth $1 billion. And even though I knew the importance of the maths within the paper on first reading it, I found it more difficult when I got to the equations. I skipped over them, told myself I'd get the details later, and moved on to the interesting bits.

The article in question was 'Computer based horse race handicapping and wagering systems: a report' by William Benter.[6] It is a manifesto, a scientific statement of intent. And it is the work of a man obsessed with rigour and full of belief in what he is doing, a man committed to documenting his plan before he carries it out, to show the world that when he wins it won't be because of luck – it will be because of mathematical certainty.

In the late 1980s William Benter set out to beat the Hong Kong horse-racing market. Before he started his project, high-stakes gambling had been an activity for hustlers. These hustlers could be seen hanging around the Happy Valley and Sha Tin racetracks, as well as the Royal Hong Kong Jockey Club, trying to gather inside information from the owners, stable staff and trainers. They would find out whether or not the horse had eaten breakfast or been given extra workouts in secret. They would befriend jockeys and quiz them about their strategy for the upcoming races.

As an American, Benter was an outsider in this world, but he had identified another way of getting his hands on inside information, a way that the hustlers had missed, despite the fact it had been lying right there in the Jockey Club offices the whole time. Benter picked up copies of the track yearbooks and, with help from two secretaries, he started typing racing results into a computer. He then had what he later told *Bloomberg Businessweek* was his breakthrough moment. He took the closing odds, also collected by the Jockey Club, and digitized them too. It was these odds that allowed Benter to apply a method similar to the one I had shown to Jan and Marius: using the betting equation. This was the key to finding the inaccuracies in the gamblers' and the tipsters' predictions.

Benter didn't stop there. In the basic equation I presented in the last section, I was limited to identifying biases in the football odds. Now, on my second or third read of his paper, I began to

understand how Benter had been profitable over such a long period of time. In my own model, I didn't look at the additional factors that would allow me to predict match outcome. But Benter did go the extra mile for horse racing. His rapidly growing data set included past performance, time since last race, age of the horse, jockey's contribution, assigned post position, local weather and many other factors. Each of these factors was added term by term to the betting equation. As he included more and more detail, the accuracy of his logistic regression, and therefore his predictions, increased. After five person-years of data entry, his model was ready and, with capital raised by counting cards in casinos, Benter started to bet on the Happy Valley races.

During the first couple of months of gambling, Benter saw a 50% profit on his investment, but this profit disappeared again two months later. Over the next two years, Benter's profits bobbed up and down, sometimes nearing 100%, only to drop again to nearly zero. It was after about two and a half years that the model really started to pay off. The profits climbed to 200%, 300%, 400%, onwards and exponentially upwards. Benter told *Bloomberg Businessweek* that, in the 1990–91 season, he won $3 million.[7] The same publication estimated that over the next two decades Benter and a small number of competitors who used the same methods made over a billion dollars at the Hong Kong racetracks.

The most remarkable thing about Benter's scientific paper is not so much its contents, but the fact that very few people have read it. In the twenty-five years since its publication, it has been cited in other scientific articles a total of ninety-two times. To put that in context, an article I wrote fifteen years ago about how Temnothorax ants choose a new home has had 351 citations.

It is not just Benter's article that has been ignored. He references a paper written in 1986 by Ruth Bolton and Randall Chapman as 'required reading' for his own work.[8] Yet, nearly thirty-five years later, this inspirational article, showing how a profit could be made on American racetracks using the betting equation, has also been cited fewer than one hundred times.

Benter had no formal education in advanced mathematics, but he was prepared to put in the work required. He has been described elsewhere as a genius, but I don't see it that way. In my professional life, I meet and work with lots of non-mathematicians

of one of these predictions was the match between Colombia and Japan. The odds for Colombia to win lengthened from 7/10 to 8/9 in the days leading up to the match. Putting these odds into our equation suggested a bet on Japan was in order. This wasn't because Japan was more likely to win the match. It wasn't. Colombia remained favourites. Instead, the equation implied that Japan, who was now at odds of 26/5, was better value than Colombia. In this particular case, we got it right, Colombia lost and we won £260 from our £50 bet.

*

Sir David Cox is now ninety-five years old and has never stopped working. In a career spanning eight decades, he has authored 317 scientific articles and there are very likely more to come. From his office in Nuffield College, Oxford, he continues to write commentaries and reviews of modern statistics, as well as making new contributions to his field.

I asked him if he went into the office every day.

'Not every day,' he replied, 'not on Saturdays or Sundays.'

He then paused and corrected himself, 'I should say that the probability I come in on Saturday or Sunday is rather small. It can happen.'

Sir David Cox likes precision. His answers to my questions were careful and studied, and always qualified by stating the level of confidence he had in his ability to answer.

It was Cox who discovered the betting equation. Well, he would never say that, and it isn't completely accurate either. A more correct statement would be that he developed the theory of logistic regression, which I used to find values of α and β, and which Benter used to determine which factors predicted the outcome of horse races.[9] He developed the statistical method that allows the betting equation to make accurate predictions.

Logistic regression was a product of post-war Britain. Towards the end of the Second World War, as Sir David finished his education in mathematics at Cambridge University, he was seconded to work first for the Royal Air Force. Later he moved to the textile industry, as the UK began the process of rebuilding. He told me that his initial interest was in the abstract mathematics he

had studied, but these placements opened his eyes to new challenges. 'The textiles industries were full of fascinating mathematical problems,' he said.

He admitted that his memory of specifics was vague, but his enthusiasm for those times shone through. He talked about how tests on various features of a material could be used to predict the probability it would break and the problems around creating a stronger, more uniform final product from roughly spun wool. These questions, combined with those he encountered at the Royal Air Force about the frequency of accidents and about wing aerodynamics, gave him plenty to think about.

It was from these practical questions that Sir David started to ask a more general question, a more mathematical question: what was the best way of predicting how an outcome – such as an aeroplane accident or whether or not a blanket would tear – was affected by various factors, like wind speed or the strains and stresses involved. This is the same type of question that Benter was asking about horses: what was the probability a horse would win as a function of its race history and the weather.

'The biggest controversies in the universities when I formulated the theory [in the mid-1950s] were about analysing medical and psychological data, predicting how different factors were related to a medical outcome,' Cox told me. 'Logistic regression came from a synthesis of my practical experience and my mathematical education. All the different problems I heard about from medicine, psychology and industry could be solved using the same family of mathematical functions.'

That family of mathematical functions turned out to be more important than even David Cox had imagined. From 1950s industry to its importance in interpreting the results of medical trials, logistic regression has been successfully applied to innumerable different problems. It is an approach now used by Facebook to decide which adverts to show us, by Spotify to recommend music to us, and as part of the pedestrian detection system in self-driving cars. And, of course, it is used in gambling ...

I asked Sir David if he knew about Benter's success on the horses using logistic regression. He hadn't heard of him. So I told him about how logistic regression had made $1 billion. I then told him

about Oxford student Matthew Benham and his success at predicting football match results.

'I prefer to say you should never gamble,' he told me after I had finished, before pausing and thinking for a very long time.

Then quietly he began to tell me a betting story of his own, about one of his colleagues in the 1950s, a story he asked me to promise never to repeat. And, I'm afraid to say, I'm going to keep to my word.

*

Betting isn't about predicting the future with certainty, it is about identifying small differences in the way you see the world and how others see it. If your vision is slightly sharper, if your parameters better explain the data, then you have an edge. Don't expect your edge to come straight away. It needs to be built up over time, through a process of trial and error, as you improve your parameter estimates. And don't expect to win all the time. In fact, only expect to win slightly more often than you lose as you play the game over and over again.

We sometimes tend to focus on our one 'Big Idea'. But what the betting equation tells us is that the key is to create different variations of our idea. Imagine you are starting your own yoga or dance class. Try different playlists with different groups and note down which gets the best response. By testing out lots of small ideas, we are running them off against each other like the horses at the Happy Valley racetrack. At the end of each race, we can reassess the winners and losers and look at the properties which led to success or failure.

If you are starting to test out a new idea, then you should perform what is known in the data science industry as A-B testing. When Netflix update their website design, they create two or more versions (A, B, C, etc.) and present them to different users. Then they look to see which design attracts the most engagement. This is a very direct application of the betting equation to the 'success' and 'failure' of design features. With all the traffic into Netflix, they can quickly build up a clear picture of what works and what doesn't.