



"Dorothy gazed thoughtfully at the Scarecrow."

INTRODUCTION

The Yellow Brick Road

If you only have brains on your head you would be as good a man as any of them, and a better man than some of them. Brains are the only things worth having in this world, no matter whether one is a crow or a man.

The Wonderful Wizard of Oz

IT WAS 1900 WHEN L. Frank Baum wrote *The Wonderful Wizard of Oz*, and over the century and more since then some things haven't changed. The Yellow Brick Road still captures an essence of the human experience. Doesn't the search for an improved life or an improved self resonate with us all? The Tin Man sought his heart along the road. The cowardly Lion, his courage. For the Scarecrow – perhaps an unlikely hero for twenty-first-century science – it was his brain.

It will be a long road for science, seeking an understanding of the brain and unlocking its secrets; but already the hows, whys and whats of the brain are unfolding on our path of discovery.

Arguably, this scientific journey started in 1848 in the US state of Vermont, where a railroad accident overturned fifteen hundred years of received wisdom about the brain. Phineas Gage was an affable and reliable man; a respected foreman on the construction of the track between

Cavendish and Burlington. Distracted by an altercation between two of his men as he packed blasting powder into a granite hole, Gage allowed his concentration to lapse. The 6-foot tamping rod was blown through his head, entering under his left eye, exiting through his left cranium and landing some 30 feet away. Remarkably, Gage recovered. *But Gage was no longer Gage.* Once sober, industrious and temperate, now he was irascible, profane, unreliable, raging in fits of anger and abuse. Inconceivable as it seemed at the time, could the damage to the brain he had suffered be responsible for such a transformation in character, personality and temperament? Gage's physician Martyn Harlow, in his famous paper on 'The passage of an iron bar through the head', published in the *Journal of the Massachusetts Medical Society* that same year, concluded that it was.

The case of Phineas Gage and the revolution in thinking it created was a pivotal moment in our understanding of the brain. No longer could organic substrate (the 'grey matter') be dismissed, as the ancients had done, as 'cranial offal'. Over the following decades, as advances



Phineas Gage holding the tamping iron that injured him

in empirical methods, imaging technology and hypothesis testing generated increasing numbers of scientific publications, the picture became clearer and we reached our modern view of the brain as an organ of immense complexity. With the false sciences of phrenology and mesmerism giving way to the real sciences of psychology, neuroscience and psychiatry, the brain ceased to be the ‘ghost in the machine’ – to the point where the axiom ‘no consciousness in the absence of organic matter’ is now an established tenet of brain science.

In 2000, one serendipitous event marked a huge leap forward. In July that year, two Scottish scientists were foraging about in the basement of the Moray House School of Education when they happened across a fifty-year-old treasure trove. It was the collected and archived results of one epic day’s work in 1947, when Scotland had done something never attempted by any other country: it tested the IQ of over seventy thousand children. This was nearly the entire nation’s population of 11-year-olds. And the unlikely reason for the investigation? It was thought that the working classes of Scotland were having too many children and were diluting the nation’s IQ (they weren’t). These unique data offered a glittering opportunity. Taking them as a starting point, researchers have been able to add a lifetime’s worth of information about these people – their individual medical records, occupations, health concerns, lifestyles and environmental influences: in short, to map out their lives and see how their thinking skills have changed over time. This priceless opportunity was turned into a scientific study. And revealed a recipe for brain power.

Called ‘The Disconnected Mind’, this sparkling study is now in its twelfth year. It has given us information about many of the changes we can expect to occur on the journey of ageing: who stays sharp and who doesn’t; what role exercise and activity play; the effects of alcohol, smoking and sex; whether friendships matter; and the impact of stress, poverty and ‘socio-economic class’. This information is our path down the Yellow Brick Road, our journey to discovering the secrets of a healthy brain. Exploiting the participants’ long lives, the study is now in

its third wave, measuring and testing about a thousand of the Lothian Birth Cohort of 1936, individuals now in their eighties.

There have been some stunning findings. For example, in a paper published in *Nature* in 2012, the study settled one of the most controversial issues in brain science: is it nature (genetics) or nurture (environment) that determines our IQ? It turns out that 50 per cent of our adult intelligence can be accounted for by IQ in childhood (at age 11). But what of other factors? It turns out that only one-quarter of the change in our intelligence – our brain power – over our adult life is determined by our DNA. Fully three-quarters of that change is determined by our environment and lifestyle factors – in other words, *by what we do*.

What else is science revealing about the brain? The rate of progress in neuroscience and psychology is prodigious. A quick list of some of the biggest breakthroughs in just the past two years will show you why I say this:

- *in vivo* cell conversion, where gene therapy is used to reprogram the brain's support cells (glia) into working brain cells;
- the idea that the neurodegenerative diseases of the brain, many of which are incurable, are *preventable*, for example by dietary changes;
- the prospect of regenerative medicine being applied to the brain, by transplanting reprogrammed stem cells;
- the discovery of new links between exercise and cognition (thinking skills);
- improvement of memory by electric stimulation of the brain;
- opening the door to deliver therapies that cannot otherwise access the brain by using ultrasound and microbubbles;

- the discovery that frequency of sexual activity is related to cognitive improvement (I'm not joking).

However, there is a problem. It is that the messages arising from this new, revolutionary research are not reaching people in a balanced and well-informed way. There is hype, confusion, contradiction. Let me give you a prime example. In 2018, a study published in the *British Medical Journal* showed a greater risk of dementia in those who abstain from alcohol completely and those who consume more than fourteen units per week. In other words, moderate drinking confers a benefit. This finding was given great prominence in the media, including the BBC and other television news bulletins. Unfortunately, the message that moderate alcohol consumption reduces the risk of dementia was put out at a time when the prevailing advice from the Chief Medical Officer was that there is 'no safe level of alcohol drinking'. We can argue the nuances of the research and the rationale behind the messages, but that is not the point I'm making here – which is that, to everyone on the ground, it was terribly confusing.

Such confusions are compounded by the many books and publications which sensationalize, exaggerate or grind the axe of personal opinion about health-related issues. There has been a profusion of health-related books, promoted by aggressive marketing, which are grossly unreliable and misleading. Nowhere is this more obvious than in the world of food and diet – including their influence on the brain. Take, for example, the matter of dietary supplements. In the USA, there are currently 85,000 dietary supplements listed by the Food and Drug Administration, and in 2018 they generated sales revenue of more than \$40 billion. The situation is much the same in the United Kingdom, and worldwide sales in 2018 were in excess of \$121 billion. Millions of people are wedded to the idea that supplements are the answer to their health concerns. Like Dorothy and her companions, we can be seduced by the notion of a wizard who will wave a magic wand and deliver our desires. Why should we expect otherwise? With a little imaginative language, manufacturers can pretty

much say what they like, as long as they don't claim to cure specified illnesses. An outstanding example is the sale of a jellyfish product that pronounces on the bottle: 'Improves Memory'. (It also pronounces itself vegetarian, which is interesting in itself since the active ingredient is an animal product – though in recent years it has been cloned.) Among the highly debatable claims the manufacturers make are: 'clinically shown to help with mild memory problems associated with aging' and 'supports a healthier brain, sharper mind & clearer thinking'. I believe none of these claims. And, as a founding member of the Global Council on Brain Health, I can tell you that they were met with derision when the Council reviewed them.¹ As I will reiterate many times in this book, I would urge you to be sceptical when you consider the many spurious and unjustified claims in the marketplace about what works and what doesn't work. Evidence is falsified, exaggerations are common and credibility is stretched – mostly in the pursuit of economic gain from an unsuspecting consumer. The key is to look very, very carefully at the evidence: both what it is and how it has been generated.

At the same time, there is a huge volume of technically complicated research findings being published about the brain. This literature is complicated because the brain is complicated – and the means by which it is studied are increasingly complicated too. It is voluminous simply because the pace of scientific advance in neuroscience, psychology and psychiatry is shockingly rapid. Day by day we are learning more. I once asked a very talented librarian what I thought was a quite straightforward question (it proved not to be so simple): 'How many scientific papers are published every day?' The answer, as near as we are likely to get, is three thousand. Three thousand per day. Since 1652, when the *Philosophical Transactions of the Royal Society* was first published, the rate at which these papers are published has doubled, on average, every nine years. The number itself is staggering. But more important is how many of them are relevant to the man and woman in the street, and of course how many of their benefits come to his and her attention.

One of the most profound revelations to emerge in the past few decades

is that ageing is a lifelong process, that it begins early in life (around age 11), and that the rate of ageing in our bodies is not only malleable but largely under our control (DNA or heredity being responsible for only about 25 per cent of it). To a large extent, we can control our brain ageing, and with it our brain health, by modifying our exposure to risk factors such as diet, exercise, sleep, sex, alcohol, coffee, stress, social connections and how we use our brains.

Which brings us back to the Scarecrow and the Yellow Brick Road. As in *The Wonderful Wizard of Oz*, there is no magical wizard to give us what we want, no miraculous single solution. Instead, mere mortal scientists are working away behind the curtain, pulling levers, helping us to understand how to make the best of ourselves using the new, exciting and revolutionary findings about what is inside us.

Dorothy longs for ‘someplace where there isn’t any trouble’. When it comes to the brain, I’m not sure we’ve found that just yet – but it is not all obstacles and peril along our personal journeys. There are helping hands. This book, I hope, will be one of them. Inspired by my work with the Global Council on Brain Health, it will separate what is important from what is unimportant, what is myth from what is fact, what we know from what remains to be discovered. It will tell you what to expect, show you the landscape, and suggest how you can negotiate the likely twists and turns as your brain changes throughout your life. It will tell you how to avoid some pitfalls, and what are the real bullets you should dodge (such as being unfit, not getting enough sleep, being obese, being unsocial). It will help you to understand how to maximize, nurture and sustain your brain health; how to stay sharp, and how to beat the signs of decline as the years go by. It will advise you on strategies for staying vibrant and keeping brain health under your own control. It will empower you with the knowledge that you can get through life in one piece, minimizing loss of brain power or performance; that mental well-being gets *better* from middle age, and that the risks of ill-health, including dementia, can be much reduced. It will also offer you a look into the future, at how the trending science is revealing the secrets of improving brain power.

Meet your brain

IN 1953, TWO SCIENTISTS at the Cavendish Laboratory in Cambridge, James Watson and Francis Crick, discovered the genetic code. Consisting of a varied sequence of just sixty-four 'base pairs', it appeared deceptively simple. It took the best part of another half-century to arrive at the entire alphabet of human DNA – the genome. This was the achievement of the Human Genome Project, which began in 1990, ended in 2000 and cost \$1 billion. It revealed that each one of us has a library of instructions for how to build a body comprising some 23,000 genes, made out of the 3 billion letters of genetic information in every cell. Now we know that this amounts to far more than just 23,000 single instructions. Each gene can code for tens of proteins – the basis of life in our cells.

If you think genetics is complex, consider the human brain: quite simply, the most complex structure known to science. So complex, indeed, that most neuroscientists will scoff at any notion that we understand it. Christof Koch, President of the Allen Institute for Brain Science in Seattle, admits: 'We don't even understand the brain of a worm.'¹ The worm he had in mind when making that comment, *Caenorhabditis elegans*, has a modest 302 brain cells and seven thousand connections – figures that rather pale into insignificance next to those of the human brain, which has 86 billion cells with thousands of connections *each*. And we are a long way from understanding even the numbers, types and function of all human brain cells.

However, what's important here is not what we don't know but what we

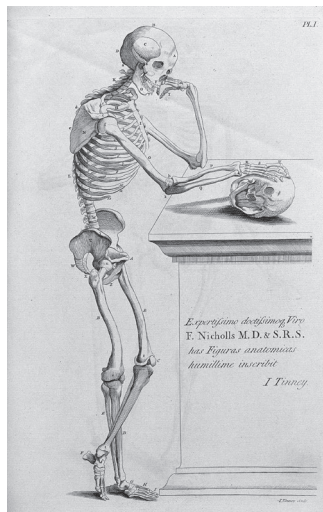
do know. Since the concept of ‘brain fitness’ came into the mainstream in 2007, scientific findings about brain health have been prodigious in scale. Brain fitness is an idea based originally on the scientific finding of ‘neuroplasticity’ – the ability of the brain to form new connections throughout life, in response to trauma, disease, new demands (such as learning) and changes in the environment. I will come back to say more about brain plasticity later in this chapter. A decisive body of research findings has now shown that, as much as our genetics, our *lifestyle* is vital to the health of our brain. These new ideas are revolutionary. They show that brain ageing begins *early in life* and is connected to *how quickly we are ageing generally*. Equally revolutionary research has also shown that *we can put the brakes on these changes – and stay mentally young*. For example, brain health in our forties and fifties can be boosted by *engaging in specific activities in the twenties and thirties* – long before most people start thinking about brain health. Just the idea that we can slow down these changes would have been laughed out of court two or three decades ago. New research has, moreover, revealed that it is never too late to improve our brain health. Whatever decade of life we are in, we have more than a fighting chance of keeping ourselves sharp.

Our discovery of the brain and what it can do has been a long journey. We are going to start by looking at a revolutionary event some five hundred years ago.

A changing landscape

Summer 1543. Andreas Vesalius, soon to be appointed physician to the Holy Roman Emperor, had much on his mind. Unwittingly – and dangerously, in a time where unorthodoxy could easily cost you your life – he was about to revolutionize medicine by publishing a groundbreaking volume, *De humini corporis fabrica*, the first empirical atlas of human anatomy. The atlas reconciled two apparently contradictory forces: hard scientific empiricism on the one hand and artistic creativity on the other. Painstakingly researched by Vesalius and allegedly illustrated by a pupil of

Titian's, Jan Stephen van Calcar, it was a monumental work of genius. For the first time in the history of humanity, the drawings of the human body were not fanciful imaginations of the artist. Astonishingly for the time, they were based on dissections of human corpses – hitherto variously banned by the Church, by the civil authorities and by the received wisdom of Galenist medicine, which followed the Greek tradition in forbidding human dissection. As if by way of a prescient but ironic twist of fate, in 1514, the year Vesalius was born, Leonardo da Vinci had been forbidden by Pope Leo X to continue with his dissections, a prohibition that would later open the door for Vesalius' totemic volume. Vesalius' success was not simply the outcome of his talent, his novel approach to empiricism and his integration of art; it owed much to the fortuitous confluence of cultural change, European intellectual advances and new technology, principally the availability of Europe's greatest ever printer and block-cutter, Johannes Oporinus. Thanks to Vesalius, an accurate anatomy of the brain in all its natural splendour now lay exposed to the eyes of the world. But what the brain actually *did* was another question entirely. Paradoxically, though physicians were now privy to the stunning



Meet your brain

beauty of the minutest intricacies of the brain, they understood nothing of its function.

Within decades of the publication of Vesalius' *magnum opus*, some hundreds of miles away in Stratford the Bard of Avon was wrestling with one of his mightiest works, *Henry IV, Part 1*. The four principal characters in Shakespeare's play were embodiments of a fallacious idea, embedded in human knowledge since ancient times, portraying human nature as a product of 'humours' in the body. Originating with the ancient Greeks, notably Aristotle and Hippocrates, this curious idea rested on the flawed perception that the body was possessed of four humours – black bile, yellow bile, blood and phlegm. The interaction of these humours explained the differences of age, gender, emotions and disposition. Their influence changed with the seasons and the time of day, and with the human lifespan. Heat stimulated action, cold depressed it. The young warrior's choler gave him courage; phlegm produced cowards. Youth was hot and moist, age cold and dry. Men as a sex were hotter and drier than women. The idea that the brain played any part in our natures would have been considered ridiculous – an absurd, risible concept.



The four humours

Such was the strength of these beliefs that Shakespeare was able to convey the commonly understood and accepted system of ‘humours’ in the four main characters of *Henry IV, Part 1* – even distributing the volume of text equally between them: Falstaff, phlegmatic; Prince Hal, sanguine; Hotspur, choleric; and the King, melancholic. Audiences loved the interplay of these characters and the underlying ideas – ideas that for over fifteen hundred years retained a grip on people, on their society, on science (such as it was) and on medicine. Until 1848. When an accident on a railroad in Vermont drove a tamping iron through them.

I have already told the story of Phineas Gage. This gruesome incident served, serendipitously, as the moment when science had to face an unpalatable truth. The received wisdom of medicine, stemming back over fifteen hundred years, was from beginning to end a fiction. For the first time, here was indisputable evidence that the seat of personality was the brain – not the heart, not the soul, and without doubt not the humours. Such incidents serve science well. Thomas S. Kuhn, a Harvard University professor, explained the utility of such moments in his 1962 book *The Structure of Scientific Revolutions*. In it, he argued that science, conservative in its approach, reserves its position until the evidence for a contrary view exceeds a critical mass, at which point the position changes. This Kuhn called a ‘paradigm shift’. The revolution in thinking about the nature of the brain prompted by the case of Phineas Gage can fairly be deemed such a shift. The 1848 paper written by Gage’s doctor, Martyn Harlow, did more than merely alert the medical profession to this gruesome case study – it set the ball rolling for a fundamental change in our understanding of brain function. Even today, two-thirds of all introductory psychology textbooks contain reference to the Gage case. And in enduring testimony to its importance, Gage’s skull and tamping iron remain on permanent exhibition at the Harvard Medical School.

Our complex brain made simple

What we know about the brain can be summed up in a single aphorism. It is the most complex entity in the known universe. The latest methods

in neuroscience have revealed that the adult human brain holds 86 billion neurons or nerve cells, each of which has 15,000 synapses or connections; 85 billion support cells called 'glia'; 528,000 miles of transmitting fibres; and a privileged blood flow of 750 millilitres (1.3 pints) per minute through 100,000 miles of vessels. In terms of cost to the body, the brain is an expensive organ. Its weight is just 2 per cent of the total, but it receives 15 per cent of the heart's output of blood. Its size has pushed the width of the female pelvis to its limits to achieve the birth of the large-brained newborn with the capacity for early walking, for language and for the social interaction necessary for group survival. And in terms of oxygen consumption, it is immensely thirsty, taking 20–25 per cent of the total for all metabolic needs, equating to some 500 calories per day – just for basic running costs. Why this startling level of metabolic privilege? Because the activity of the brain controls not only all aspects of all our basic survival mechanisms – body temperature, water level, acidity, blood pressure, hormone regulation, posture, balance, movement – but all our higher-level thinking (planning and decision-making), our social engagement with others and our emotional control.

In the most basic terms, however, the brain may be viewed as little more than a bag of salty water. Or, to be more precise, a bag consisting of a long, folded tube, with walls at their most only 5 millimetres thick. How could such a basic structure ever comprise the most elaborate organ in the body? We see the answer to this question in the development of the brain in the human embryo. Our brain begins to take shape at about twenty-one days after conception as a simple tube, the neural tube. From that point, at the front ('anteriorly') it greatly expands sideways ('laterally') either side of the mid-line. These expansions become the 'cerebral hemispheres' – the two halves of the brain. They are not completely separated but communicate with each other by means of a broad band of tissue, the corpus callosum ('hardened body'), and there is evidence that the female brain becomes more adept than the male at this 'cross-talk'. Researchers at the University of Pennsylvania scanned the brains of four hundred males and five hundred females aged between eight and 22, and after age

13 they found far more connections between right and left hemispheres in the female brain, facilitating more emotional processing and therefore social interaction.

Next comes a remarkable development. Starting about thirty-five days after conception, the front part of the tube migrates upwards and backwards, folding over itself so that the tip lies at the back of the hemispheres. It is during this phase of development that the elaborate folding occurs to give the brain its familiar ‘walnut’ appearance as a mass of ‘gyri’ (folds) and ‘sulci’ (grooves). This folding takes place for one purpose only – to pack as much brain material as possible into the confines of our cranium. The thin walls of the folding brain surface are what we call the ‘cortex’; this, were it to be unfolded, has a surface area of 1.5–2 square metres – about the size of two pages of a large newspaper. Only in this way can our 86 billion neurons coexist within our 1.4 kilogram brain. It’s probably worth mentioning here that brain size differs considerably between people at maturity, and women generally have smaller brains than men. But before all the men start to get smug, it’s also worth mentioning that brain size is only weakly related to general intelligence. In 2012, a review of the evidence by Professor Richard Nisbett of the University of Michigan concluded that there was no significant difference between the general intelligence of men and women – echoing the findings of Jensen in his classic work some forty years earlier.

The building of the brain is a mammoth task on a tight timeframe – some 250,000 neurons are produced *per minute* throughout the course of pregnancy. The neurons are so closely packed that their dark, DNA-containing nuclei give a grey tint to the cortical brain matter – our proverbial ‘grey matter’. And yet the mature brain is so sophisticated that a two-year-old’s is only 80 per cent of its finished size – it does not finish developing until about age 25. As they are produced, new cells move to a predetermined area of the brain and then turn into – ‘differentiate’ into – the specialist cells of that area, eventually forming the various structures shown in figure 1.1. The maintenance of the brain is so important that at least 50 per cent of it – a much higher proportion in the highly active,

sophisticated cortex – is made up of support cells called glia, which protect and support functioning neurons. There are several types of glia, including oligodendrocytes, which insulate the brain’s wiring (white matter). This white matter – so called because of its fatty content – along with countless fibres, forms the interconnections between all the brain’s 86 billion cells, known as the brain’s connectome. The hemispheres are connected by transverse fibres, such as those of the corpus callosum. Association fibres link the different regions within the hemispheres, and projection fibres link the regions to the spinal cord.

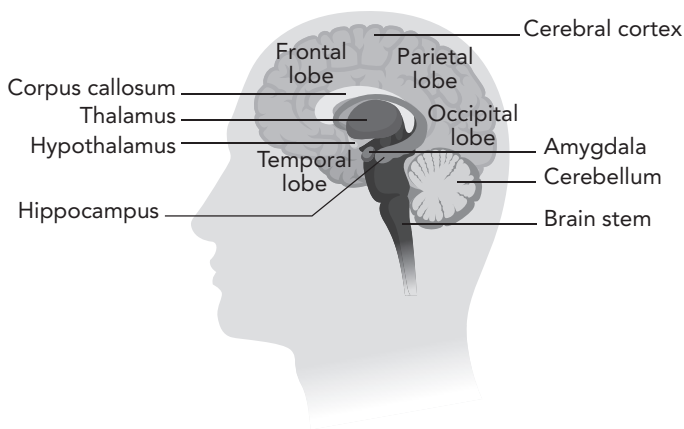


Figure 1.1: The human brain in situ

Situated above and below the corpus callosum are a number of bodies that together make up a powerful, ancient structure – the limbic system, known to psychology as the ‘emotional brain’. Called ‘limbic’ from the Latin *limbus*, meaning border, this powerful system includes elements of our ‘thinking’ cortex – areas such as the hippocampus – and deeper, more primitive structures such as the hypothalamus, amygdala and thalamus, all shown in figure 1.2 overleaf. The hypothalamus is our critical control centre, regulating our hormones, sexual behaviour, blood pressure, temperature, hunger and thirst. The amygdala is our powerful ‘anger machine’, controlling anger, fear, anxiety and stress. Then we have

the thalamus – a vast processing centre for all the sensory information coming into the brain from other parts of the body, such as visual images, sensations – including pain – and temperature. Critically, it tells the brain what is going on in and around our bodies – and reacts to all of it. It also plays a key role in our arousal or alertness levels. Not for nothing has the limbic system been called the ‘feeling–reacting’ brain as opposed to the ‘thinking brain’. It has one, vital, overarching purpose: survival and self-preservation. Connected to the rest of the body by a two-way high-way running in and out of the brain, it generates powerful reactions that permeate our whole being. Some behaviour we can’t explain. Some we can’t understand. Some is immensely difficult to control. The red mist of anger. The impulse to flee in terror. The compulsive drive to love, hate or enjoy. All these deeply felt experiences derive from the uncontrolled activities of our ‘emotional brain’.

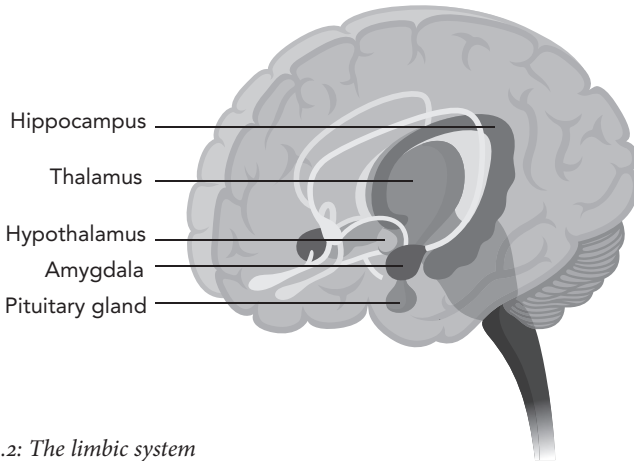


Figure 1.2: The limbic system

The limbic system is dominated and kept ‘under control’ by the crushing weight of our social values, learned (or not!) and stored in the frontal lobes of the cortex. Temporarily incapacitate the frontal lobes through the anaesthetic consumption of alcohol, and uninhibited limbic behaviour frequently results – aggression, rage,

anger, unbridled lust. Permanently disable the frontal lobes by a full-frontal lobotomy – a fate suffered by Jack Nicholson in the movie *One Flew Over the Cuckoo's Nest* – and pacification results, as the ability to scheme and plan is lost.

One of the emerging changes in thinking about the brain is a shift away from the idea of ‘localization’ of function – the idea, first put forward in 1878 by John Hughlings Jackson (a Fellow of the Royal Society and physician at the London Hospital), that certain parts of the brain are dedicated to a single function – movement, for example; or vision. The idea became embedded in medical orthodoxy after a furious debate in 1881 between the German scientist and vivisectionist Friedrich Goltz and David Ferrier, a pupil of Hughlings Jackson. Goltz lost that debate – but modern neuroscience has shown that he may well have been right, as it is becoming increasingly clear that the many areas of the brain work together seamlessly in a totally integrated manner. Surprisingly, for example, it’s been found that more traffic occurs *from* the visual cortex *to* the thalamus than vice versa, even though we would expect the latter to be the case, given the routing role of the thalamus. It appears that as the visual cortex receives incoming messages from the eye, it constantly checks them against the resident images (our ‘world-view’), accessed from the hippocampus via the thalamus, to understand what our senses are telling us. Sophisticated functioning requires a sophisticated, interconnected system.

And what of the unfolded remainder of the neural tube? It becomes the conduit of the brain–body tract: the spinal cord, the highway by which the most functionally advanced parts of the brain receive and convey life-sustaining and, for the most part, subconscious messages for which we give the brain little credit. With few exceptions, information about everything happening in the body finds its way into the brain through the spinal cord and cranial nerves, largely via our thalamus, that vastly powerful sub-cortical switchboard. Conversely, everything happening in the brain is directed by messages to the body. Without this vital reciprocal control pathway, everyday life would be impossible.

The lengthy and intricate development of the human brain makes us a species extraordinary, an exception to the evolutionary rules that apply to other primates. The frontal lobes represent a larger percentage of the cortex in the human (29 per cent) than in either the chimpanzee (17 per cent) or the rhesus monkey (11.5 per cent). But our higher thinking or cognitive skills are not attributable solely to our much larger 'pre-frontal' cortex. What matters is not so much size itself as the way in which the cortex is organized: the neurons of the human brain have a much more complex array of connections, which scientists call 'dendritic arborization' (a typically Latinate phrase meaning, essentially, a 'tree-like' pattern). And we have a much larger volume of white matter than could possibly be predicted from estimates of our grey matter. We truly have the most highly connected brain of any species – and that is particularly true of the female brain, which, as I mentioned a little earlier, shows more connections between left and right hemispheres – higher white matter complexity – than the male. It is no wonder that we became the supreme primate. In almost all respects, it would be true to say that whereas every other animal species on the planet survives by adapting to its environment, humans have survived as much by changing their environment as by adapting to it. By working together in ruthless social groups, and by working to temper primitive, emotional behaviour with the cold imperative of logic, we have harnessed the capacity of our large brains to overpower the natural world, inventing and reasoning ourselves to the top of the food chain. Little has been able to outpace the unstoppable momentum of this supremely intelligent species, empowered by group action, cooperation and the staggering capacity of the evolving human brain.

Brain health: the three core functions

Our ideas about health have changed dramatically in the past fifty years. No longer is it thought of as just the absence of disease. Now we see it as involving our capacity to cope with the changing physical, emotional

and social pressures around us – our ability to adapt and self-manage. In no area is this more true than in the health of our brain – which, given the organ's vast complexity, could be conceived of as a maintenance nightmare. The crux of brain health is our ability to function well in daily life and work. Essentially, good brain health involves exercising three central functions of our brain: executive function (decision-making, problem-solving, reasoning, learning and memory); interacting successfully with others – what neuroscientists call 'social cognition'; and enjoying emotional balance or well-being.

Which television stations do you watch? What coffee did you choose this morning? Did you cook supper last night or eat out? Did you decide to walk the dog or just stay in? It sounds like a pretty truncated and mundane list of decisions, but neuroscientists at Yale have worked out that the brain (that is, every one of us) makes an astonishing 35,000 decisions *every day*. Assuming that we spend around seven hours asleep (blissfully decision-free), that works out at roughly two thousand decisions per hour or one decision every two seconds. To make these decisions, we need awesome computing power. And awesome it is: the brain has a memory capable of holding 1 trillion bytes of data and can turn over 100 trillion operations per second. Only the largest computers get anywhere close (more on this in a later chapter). This, in summary, is the executive power of the brain. Problem-solving, reasoning, learning all depend on it. This power has evolved from the need to out-think and out-perform the competition – whether predator, prey or a fellow human. In modern life we are not under quite the same survival pressures that our ancestors faced, but pressures we have none the less. Now new science is showing us how to stay sharp throughout our longer lives, how to resist the erosive effects of stress, and how to maintain our attention and think clearly in an age of information overload. Throughout this book, these pressures will be analysed chapter by chapter, along with strategies for handling them, to give you a bible of advice for maintaining your brain power. For example, it's now known that we can speed up the brain's activity through practice. In an experiment at Vanderbilt University,

students had their multi-tasking tested. They had to identify which one of two possible faces appeared on a screen while responding to one of two possible sounds. After just two weeks of practice, the participants could do both tasks in rapid succession almost as quickly as doing either one on its own.

So much for executive function. What about social cognition? Social cognition is how the brain processes, stores and applies information about other people and social situations. This was at the root of what gave humans the edge over other primates. Around a hundred thousand years ago, in the competition for survival and dominance, the human brain developed superior cognitive networks for group working with other humans. This essential survival asset underpins all human society, all its rich social networks and the benefits they confer. And if humans got the edge over other primates, women got the edge over men. New science has confirmed what we always suspected: women are better at sending and receiving non-verbal social messages, including reading emotion in facial expressions, gestures and body language. Research shows that seventeen out of twenty women are more accurate at decoding social cues than the *average* man of the same age. These advantages are especially marked in female-only groups – that is, women read other women even better than they read men. These findings can be explained by the different ways in which the female brain is wired; and this difference in turn may be explained by the different selection pressures in biological evolution. In later chapters, we will see the devastating effect of social disconnection on how our brains function.

Reading other people's emotions is one thing. Managing your own is another. Keeping an even keel is a big, big deal. Without that ability, performance suffers and social relationships go out of the window. It is a high-stakes game. An errant individual in a hunting party could cost the group its prey – and with it, its survival. An emotionally out-of-control individual has the potential to wreck social and interpersonal relationships, costing the group its cohesion and again threatening its survival. The evolutionary key to this problem was the development of a

huge pre-frontal cortex – our frontal lobes – providing massive inhibitory power to regulate the emotional drives of our so-called ‘reptilian brain’: anger, rage, aggression. Emotional balance occurs when we allow our conscious mind to understand, regulate and accept our feelings without letting them drive our behaviour. New findings are showing us just how and why these mood states arise – and what we can do about them. For example, in the past ten years the new science of psychobiotics has revealed that one big and surprising factor is the activity of the microbes in our colon, which can determine our emotions and our feelings – an amazing concept. We shall come back to this in chapter 4, ‘Bugs in the brain’.

How our brain changes with time

Science can now show us what to expect of our brains as we travel through our lifespan. It’s now possible to track our cognitive abilities or ‘thinking skills’ through the use of neuropsychological tests, and neuroscientists have found that most people are already showing declining ‘spatial’ skills by the mid-twenties. Our memory and reasoning start to slow down marginally in our early thirties, and by the middle of that decade we are processing information more slowly. Although these changes are initially subtle, they add up with each passing year and become more noticeable after age 50, when our ‘forgetting moments’ often start. In a study that examined the ‘pace of ageing’ in young adults aged 26–38, those who showed more general biological ageing – identified by a number of health indicators – than their (theoretically estimated) predicted rate also showed greater cognitive decline and brain ageing by as young as 38. They even looked older! In other words, the rate of brain ageing is related to the ageing of other bodily systems, such as the lungs and heart, the liver and kidneys, and the immune system, even at a young age. So it seems that we can predict how our brains are doing by looking at our general health. I’ll return to this point later in the chapter.

We should all be concerned about maintaining our memory. It’s as

important as our physical health, if not more important. Your short-term memory enables you to remember the words you are reading so you can understand this sentence when you reach the end of it! Your long-term memories form the basis of your personality and your life. Memory, however, is much misunderstood. Evolution never intended us to have a video-recorded memory which would store everything we saw, heard or experienced. Our memory evolved to enable us to think, plan and do what we needed to do to survive, not to give us total recall. Our memory isn't even reliable. Far from it. For our 2 million years or so of human existence, it's worked well enough – as the expression goes, it's 'close enough for government work' – but it was never intended to cope with today's technologically laden world. And finally, there's no logic to the way our memories are stored, or which details we remember. We construct them on the largely emotional basis of what rewards us or what is important to us.

Take one feature of memory that drives most of us mad – the inability to put a name to a face. First, we should recognize that 'face blindness', as it's sometimes called, is experienced by everyone to a greater or lesser extent. It's just that younger people (in general) don't worry about it so much, whereas the rest of us become preoccupied with it and embarrassed by it. What neuroscience tells us is therefore very reassuring: we're bad at remembering names because there's no reason why we should be good at it. Faces carry meaning, tell a story, evoke our emotions. But names alone tell us very little. And further, our short-term memory will drop any meaningless item unless it is rehearsed. The lesson here is not to identify a common and apparent failing as a sign that we are 'losing it'. The evidence, to the contrary, is that we can stay sharp much longer than popular culture would have us believe.

Brain plasticity, also called neuroplasticity or neural plasticity, is the brain's ability to undergo structural and physiological change to cope with new threats and challenges. It enables us to respond and adapt as the result of experience. It occurs through changes in the synapses and the growth of new brain cells. Neuroplasticity was once thought

to occur only during childhood, but research in the latter half of the twentieth century showed that many aspects of the brain can be altered (are 'plastic') throughout adulthood – that plasticity lasts, as Norman Doidge put it in his book *The Brain that Changes Itself*, 'from the cradle to the grave'. This means that many of us will be able to remain mentally acute and competitive, picking up new skills, throughout the greater part of our lives – even out-performing people much younger than ourselves as we deepen our knowledge and master new activities. Which is great news for anyone in fear of competition from younger, more ambitious and apparently 'sharper' colleagues.

There is no better example of brain plasticity than a hemispherectomy, a surgical procedure where one half of the brain is removed. This operation sounds too radical ever to consider, much less perform, so readers may be relieved to know that it is only carried out when the alternative is worse (for example, when death is threatened from a fatal disease, such as Rasmussen's encephalitis, in one half of the brain). Unbelievable as it sounds, the brain is so resilient and adaptable that even this extreme surgery has no apparent effect on personality or memory – they are conserved in the non-affected part of the brain, entirely due to the plasticity of the neurons. Certain brain functions which are unilaterally located (such as the speech centre in the left hemisphere) also appear to be taken up by the opposite hemisphere over time. There are some deficits that persist after surgery: for example, in a study of fifty-eight children who underwent this operation to control unremitting epilepsy, almost all emerged with 'hemiparesis' (one-sided weakness) in the contralateral arm (the one on the opposite side to the part of the brain removed), but all of them could walk and some could run. The point is that the anticipated effects of such drastic surgery are mitigated by the plasticity of the brain – in this case, its capacity to change and adapt after trauma. Plasticity is an inherent property of our brains and is the key to maintaining our brain functions.

Looking after our brains

How should we look after our brains? It is a daunting question. Longitudinal studies – where individuals are recruited as children or infants and then followed through their lives – are probably the best method of all for identifying the factors at play in keeping our brains sharp. Such studies can help to tease out the relative influences of genetics, epigenetics (changes due to how existing genes work) and environment. The evidence in the Disconnected Mind study has shown, for example, that 50 per cent of our intelligence in adulthood can be accounted for by our childhood IQ. Of the remaining 50 per cent, about one-quarter is attributable to our genes. That means that three-quarters of the change in our intelligence over the course of our lives is attributable to lifestyle: what we call ‘modifiable risk factors’. We still have a long way to go in gathering enough evidence to be certain about the effects of each of these factors on our brain. The various chapters in this book deal with most of the important ones, such as exercise, sleep, sexual activity, social relationships, stress and well-being, and our gut microbes, nutrition and brain activities. However, probably the best general principle is to look after our general health – and, in particular, to keep on top of something we call low-level, long-term inflammation.

We normally think of inflammation as the acute response of the immune system to an injury or infection. The manifestations first described in AD 100 by the Roman author Cornelius Celsus as *rubor et tumor cum calore et dolore* (redness and swelling with heat and pain) became the hallmark clinical diagnosis of inflammatory disease. Essentially, inflammation is a protective reaction of the immune system. However, inflammation may also be chronic: that is, a low-level response over long periods of time to stress and to sustained long-term conditions, such as diabetes, obesity and arterial disease. It is a subtle but invisible process that is going on in our bodies on a daily basis and increases as we age; that is to say, the general level of inflammation in our bodies increases year by year. Even if we have no long-term illness

and even if we are apparently healthy, a certain level of inflammation in the tissues will accumulate as our immune system responds to the challenges and stresses of daily life. Low-level inflammation in this respect receives little attention. Science has now identified ‘inflammatory markers’ – molecules which appear in the blood as a reaction to trauma or stress: cholesterol, C-reactive protein (CRP), cytokines, fibrinogen and many more, all of which are indicators or predictors of current, imminent or future illness. The immune system produces these molecules as a response to damage, infection or other changes in our tissues. For example, CRP acts as a ‘surveillance’ molecule, providing a ‘look-out’ or early warning signal for the immune system that something is amiss. But they also predict the rate at which our body and our brain are ageing.

This age-related increase in inflammation is an inevitable process; but the great news is that we now know that we can slow it down – and keep our brains more vital and healthy as we do so. If we reduce high levels of inflammation we slow down the overall rate of ageing in the body, reducing our risk of long-term illness, including brain conditions. On average, someone aged 30 or 40 will have no chronic illnesses; but by 65 the average person will have been diagnosed with one long-term illness, and the average 85-year-old will have five or six diagnoses and be taking ten to fifteen prescribed medications. Simple observation tells us that some people go on looking young, stay young in outlook and live long, engaged, productive lives. Sadly, for others, the reverse happens: early chronic illness, poor productivity, loss of independence and probably a shorter lifespan. Until the past few decades, these individual differences could not be adequately explained. Now we know that ageing is a lifelong process, beginning around age 11, and is subject to the influence of ‘modifiable risk factors’ throughout our lifespan; and that these factors are all, to some degree, inflammatory. I have mentioned some of them: diet and nutrition, sleep, social life, physical activity, alcohol, tobacco, drugs and stress. For example, every time we eat, the level of inflammation in the body rises, simply because we are ingesting foreign matter – and the more we eat, the greater the

inflammation. Sleep badly and inflammation rises. Get ‘stressed out’ and our inflammatory markers rise. These changes can occur at any age. They apply at age 20, 30, 40, 50 and on until death. But as we get on in years, our bodies deal with them less well; so it is imperative to take action to reduce inflammation as we grow older. The relationship between age and inflammation is so strong that some scientists refer to the combination as ‘inflammaging’.

It is true that as we become older, changes occur in all parts of the body, including the brain. Certain parts of the brain shrink, especially those important to learning and other complex mental activities, and communication between neurons can be reduced. Blood flow in the brain may also decrease, especially if the arteries harden. And we know that neuro-inflammation in the brain, like inflammation in the rest of the body, increases with age. But the extent of these changes can be slowed down – and that is the principal message of this book. Every diagnosis of dementia or ‘mild cognitive impairment’ (a decline in thinking skills) is preceded by twenty to thirty years of neurodegeneration and inflammation. Over 42,000 people under the age of 65 in the UK have dementia. So, in these people – astonishing as it may seem – the disease process would have started as early as age 35.

Dementia and other forms of cognitive decline are among the most feared aspects of later life – to the extent that they are often referred to as ‘the new cancer’. In the 1950s, cancer was most often diagnosed late and couldn’t be cured, leaving sufferers and those close to them with a sense of defeat and helplessness. Today, while cancer treatment has improved, our understanding of dementia and our ability to treat it are still very new science. Until recently, no one knew whether or not anything could be done to prevent the effects of degenerative change in the brain. Until the FINGER Study, that is.

On a cold December day in 2013, in Lancaster House, London, the then Prime Minister David Cameron brought together three hundred of the world’s brightest brains to consider strategies to deal with Alzheimer’s disease and dementia. It was an epic first, and Britain rightly received

many accolades for convening this G8 conference on one of the most intractable and, some would say, unavoidable crises of our times – an inevitable result of our ageing population. Though the focus was on a cure (with a target date of 2025), in an unusual move the G8 mooted the idea that if we couldn't yet cure dementia, we might at least reduce the risk of it. Prevention was the dark horse coming in on the blind side. Few people were convinced. However, we already knew in 2013 that if you are middle-aged, of low educational attainment and have high blood pressure, obesity and/or diabetes; if you are physically inactive, a smoker or have depression – then there is a big chance you will eventually have dementia. The trouble was, the evidence was only by association. We didn't know for sure that if you removed these behaviours, then dementia would be prevented. But there was a lot of expectation riding on a study that was under way at the time of that conference; and a year and a half later, in June 2015, the findings of this study – the FINGER study – were published in the *Lancet*.

FINGER – the Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability – was undertaken over two years. It followed 2,554 people aged between 60 and 77, looking at the prevention of 'cognitive [brain] decline' by comparing two groups – one which followed advice on diet, exercise, cognitive training and vascular risks, and one which was given just general health advice. The result was clear, and startling: the interventions improved or maintained the cognitive status of at-risk individuals and reduced their risk of cognitive decline. The authors of the study concluded that if the beneficial effects on cognition observed in FINGER led to even a modest delay in the onset of dementia and Alzheimer's disease, they would have a huge effect at both individual and population levels.

So important are the results of this study that the World Health Organization has set up WW-FINGERS, a network of prevention (or, more properly, risk reduction) trials around the world. The 'take-home' message for us is that it's possible to reduce the risk of cognitive decline using lifestyle interventions. Quite simply, the study has shown that there

is great value in reducing the risk factors in our lives, promoting our overall health and reducing our risk of getting chronic diseases.

And we can start doing this at any time, at any age. In the introduction, I mentioned the world-famous Scottish study ‘The Disconnected Mind’. I was once asked on the BBC *Today* programme what was the most startling finding to emerge from it. For me, there was only one answer. In the original IQ test of over seventy thousand children, no one achieved a perfect score. In the same test over six decades later, many of the same individuals, who were now on average 74, did – to the astonishment of the research team. What a brilliant and incontrovertible response to all the cynics who say that we can’t stay sharp, can’t keep up, can’t stay on the edge as we pass through 30, 40, 50 and beyond. History is full of people of all ages who have become great thinkers, leaders and achievers: Jo Pavey, who at 40 won the European gold medal in the 10,000 metres; Diana Nyad, who swam from Florida to Cuba at 64; Winston Churchill, who became Britain’s wartime leader at 65; Lord Palmerston, Prime Minister at 71; Peter Roget FRS, who invented the thesaurus at 73; Nelson Mandela, who became South Africa’s President at 76; and Dorothy Hirsch, who reached the North Pole at 89. The list is endless. And inspiring.

So: contrary to common belief, our brain performance won’t necessarily go on a downward slope as we get older. The evidence shows clearly that some people *improve* mentally with age. This includes maintaining high childhood levels of intelligence – which are in most people very stable; but other mental skills, such as vocabulary and word use, *improve in almost everyone*. Psychologists refer to these skills as ‘crystallized intelligence’, and distinguish them from ‘fluid intelligence’, a more difficult skill to maintain. This ‘fluid intelligence’ is the general ability to think abstractly, reason quickly, discern relationships, recognize patterns and *solve problems*. Fluid intelligence can be your secret weapon. It’s not dependent on education or qualifications. Nor on your experience or how much you know. But it will help you to be a great problem-solver – a very attractive proposition. It’s the kind of skill you need for what is sometimes called ‘out-of-the-box thinking’, and it will make you innovative,

creative and exceptional. How can you nurture it? That question has been plagued by forty years of uncertainty; but new evidence shows that fluid intelligence is to an extent trainable. By challenging the brain, working out of your comfort zone and taking on activities you normally shy away from, the chances are you will improve your fluid intelligence. One of the big messages of this book is: ‘challenge your brain’. New experiences, new skills and even new threats are key to keeping your mind sharp.

Brave new world

Neuroscience, and the influence it has on our everyday lives, is advancing like a wildfire. Should anyone doubt this, I list here *just a few* of the many developments, many of them stunning and some even frightening, which have happened in the past two years alone. Take a look:

- It's now become possible to interface the brain with computers – an astonishing breakthrough with huge promise (and risks). An exciting study at the University of California, San Francisco, has shown that a computer may be capable of translating brain signals into words. And by late 2020, brain–machine interfaces were being developed by some US corporations, including among others Neuralink (founded by Elon Musk).
- A study in April 2019 found that the adult human brain is able to produce new neurons until the tenth decade of life – that is, our brain renews itself even into our nineties: clear proof of neuroplasticity and the potential for maintaining brain health and performance.
- Foods high in sugar have been found to reward the brain exactly in the same way as hard drugs, such as cocaine and heroin.

- Researchers at Johns Hopkins University have found that Parkinson's disease begins in the gut and migrates to the brain; and the Flemish Gut Flora Project showed that gut flora are related to depression. (I'll come back to this in more detail in chapter 4, 'Bugs in the brain'.)
- New kinds of electrical signals in the human brain have been discovered that separate us out from other species.
- The US Food and Drug Administration has approved Spravato ('ketamine' – the party drug and horse tranquillizer) as a nasal spray for the treatment of depression in adults.
- Challenging the idea that brain death is final, Yale researchers revived the disembodied brains of pigs four hours after the animals were euthanized. A frightening study, with huge implications for ideas about consciousness.
- And while we're on consciousness: scientist have produced 'mini-brains' which may have the capacity to think. Mini-brains are neuron clusters 5–6 millimetres in size, grown in the laboratory, which organize themselves into brain-like structures. They raise the nightmare view of a disembodied brain conscious of being trapped in some never-ending cycle of pain and suffering.
- The US corporation Biogen has resurrected the drug aducanumab for approval as a treatment for Alzheimer's. This development has had a huge impact on pharmaceutical companies, many of which were disengaging from the search for neurological cures. To put this development into perspective, as yet we have no cure for any of the four hundred neurological diseases classified by medicine.

Some of this, I admit, makes uncomfortable reading. So, in the spirit of the advice presented in this book, if you find some of these and other edgy findings disturbing, de-stress with some physical activity – research has shown that twenty minutes should do it. To give you a flavour of what is to come in the remaining chapters, here are just a few of the suggestions they will make: declare war on the chair to give you the edge (chapter 2); chew gum for added brain power (chapter 4); take Vitamin B6 before jumping out of a plane (chapter 5); and have more orgasms – they’re good for the brain (chapter 7). I hope these points, and all the other advice that follows, will give you a greater understanding of your own brain and how to nurture it. Your life depends on it.

Body and mind

IN 2004 TWO DEMOGRAPHERS, Giovanni Pes and Michel Poulain, identified an obscure region in Sardinia as the part of the world with the most centenarians. As they narrowed their search, they drew blue concentric circles until they captured the exact location of peak longevity. Seizing the opportunity, Dan Buettner, a US explorer and author, worked with Pes and Poulain to identify four other locations blessed with high longevity (not entirely easy: one of the main findings was a strong association between claims of longevity and poor record-keeping!). These were Okinawa, Loma Linda (California), Costa Rica and the Greek island of Icaria. All five of these areas – first called the ‘Blue Zones’ in the November 2005 edition of *National Geographic* magazine – shared nine common features. One of them was moderate, regular and prolonged daily physical activity. As a way of life.

In all these populations, the way of life involved walking for ten thousand steps every day – at the very least. As shepherds, goat-herds, farmers. No one ever joined a gym, had a personal trainer, worked out or ran marathons. In their unwitting wisdom, these people foreshadowed the health advice now considered the vanguard of scientific progress, designed to overcome the ill-effects of our modern lifestyles, imprisoned as we are by hours every day in the car and/or at the office. The demise of physical labour in all fields of occupation places us in conflict with our natural physiology – developed not just for the relatively recent Neolithic farming conditions of ten thousand

years ago, but over 1.5 million years of human evolution, through which survival was to a large degree dependent on the ability to gather and to hunt. Almost as if obeying a law of physics, our Western, sedentary lifestyle has been plagued by degenerative ailments – obesity, diabetes, heart disease and dementia. And, as if demonstrating the same law from the opposite direction, in the Blue Zones dementia and other forms of mental decline are rare – about 75 per cent less frequent than elsewhere in the Western world.

Evolution, modern life and physical activity

In the early 1830s Sir Charles Lyell, a lawyer and Professor of Geology at King's College, London, put forward what was then an astonishing (and provocative) idea. Not only was the Earth many millions of years old – but it had been shaped by climate change no different from that occurring now.

Geology tells us that the most prevalent condition of the Earth is glacial, that is, covered in ice. The last ice age ended a mere ten thousand years ago. It had lasted 2.6 million years. For three hundred thousand of those years, anatomically modern humans had occupied the planet, evolving as 'hunter-gatherers'. Then came an epic change in climate that tipped us out of the ice age into the Neolithic era: the warmer weather made agriculture feasible, and farming was born. It arose simultaneously in several areas of the globe, most famously in the Middle Eastern 'Fertile Crescent' (modern-day Iraq), and then spread to Europe. With it came profound changes in our behaviour and the type and levels of our physical activity, as we moved away from nomadic existence over vast areas towards settled farming, though the herding of animals still required long daily periods of walking.

The hunter-gatherer epoch had earlier laid down the evolutionary template for our modern bodies. In conditions of food scarcity, our physiology developed to support prolonged periods of hunting, involving long, slow treks interspersed by intense killing activity; then eating

voraciously while food was available; then resting, to store and conserve energy for the next hunt – or for evading predators or for seeking a mate. Interestingly, as our ancestors moved from a scavenging to a hunting lifestyle there was a reduction in what is called ‘sexual dimorphism’. In other words, male and female become less different from one another – so that, for example, female physical sexual signalling involves no conspicuous change in bodily appearance. The principal beneficiary of this change was reproductive capacity: unlike other primates, the female human is fertile, and so receptive, throughout the year – a phenomenon described by behavioural physiologists as the ‘ERV’ (‘Ever Ready Vagina’). This means, in essence, that human group survival is more resistant to the pressures of population reduction because females can have children throughout the year. But that increased fertility meant that to get enough food to support the increased numbers of children, they were even more dependent on hunting *and therefore on physical activity*.

This survival-driven shift towards high episodic levels of physical activity as hunters was a critical event in our evolution. Hunter-gatherers used mobility as a survival mechanism, no longer relying on scavenging the food remains left by other predators but seeking out their own prey over vast distances. It is estimated that a hundred-strong hunter-gatherer group would require between 500 and 700 square miles of territory to support itself. Hunting placed a high premium on our physiological capability to maintain the health of our organ systems – our cardiovascular system, our endocrine system, our musculoskeletal system. And our brains. The evolution of our brain was driven by movement, prioritizing awareness, response, reaction, adaptation. And so, as modern science is revealing, the brain’s health is dependent on the embedded need for physical activity.

Essentially, our physiology has not changed for 1.5 million years. Evolution has moulded the primordial clay of our human frames; recognizing this helps to explain the impacts of our current more sedentary lifestyle on our physical and mental health, and how we can use this evolutionary context to improve our well-being today.