



# THE 21<sup>ST</sup> CENTURY BRAIN

Cutting edge neuroscience to  
help us navigate the future

**DR HANNAH CRITCHLOW**



## About the Author

**Hannah Critchlow, PhD, Hons DSc** is an internationally acclaimed neuroscientist, broadcaster, author and Fellow at Magdalene College, University of Cambridge. Her expertise lies in consciousness, learning and memory, decision-making, intelligence, collaboration between minds, and our relationship with AI. She has two doctorates: her research PhD investigating synaptic plasticity from Cambridge University, completed in 2007, and an Honorary Doctorate from Brunel University, received in 2022, for her global contribution to neuroscience and communication. In 2019 she was named by *Nature* as a ‘Rising Star in Life Sciences’ and was recognized as a ‘Top 100 UK scientist’ by the UK Science Council. In March 2026 she received the Rosalind Franklin Lecture Medal from Humanists UK.

Hannah has appeared on the BBC, Australian ABC, and Korean TV and radio and gives regular talks to diverse audiences across the world. Her previous books are *Consciousness: A Ladybird Expert Guide*, *The Science of Fate* and *Joined-Up Thinking*.

ALSO BY DR HANNAH CRITCHLOW

*Consciousness: A Ladybird Expert Guide*

*The Science of Fate*

*Joined-Up Thinking*

Dr Hannah Critchlow

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THE 21ST CENTURY BRAIN

*Cutting-Edge Neuroscience to Help Us Navigate the Future*



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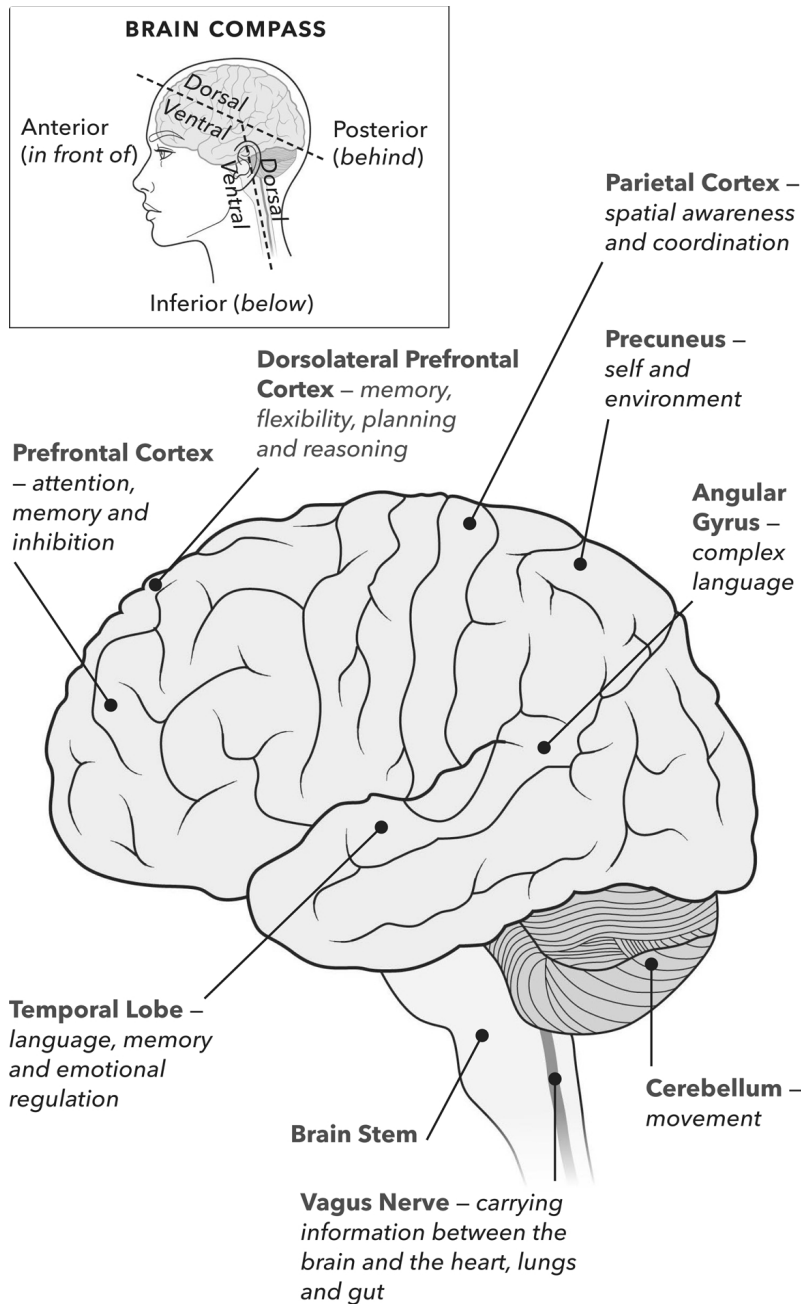
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To my son, Maxen, whose boundless energy, sense of  
adventure and love for play continue to inspire me in  
this 21st-century world.

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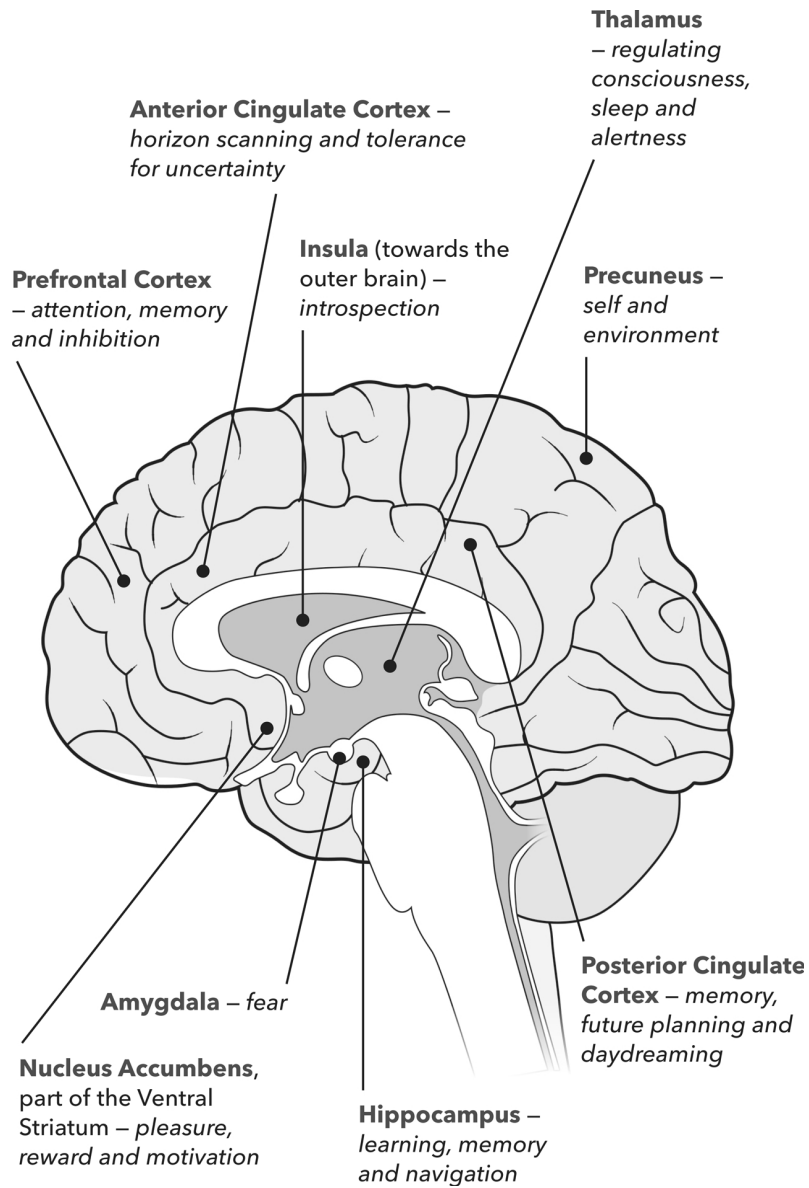
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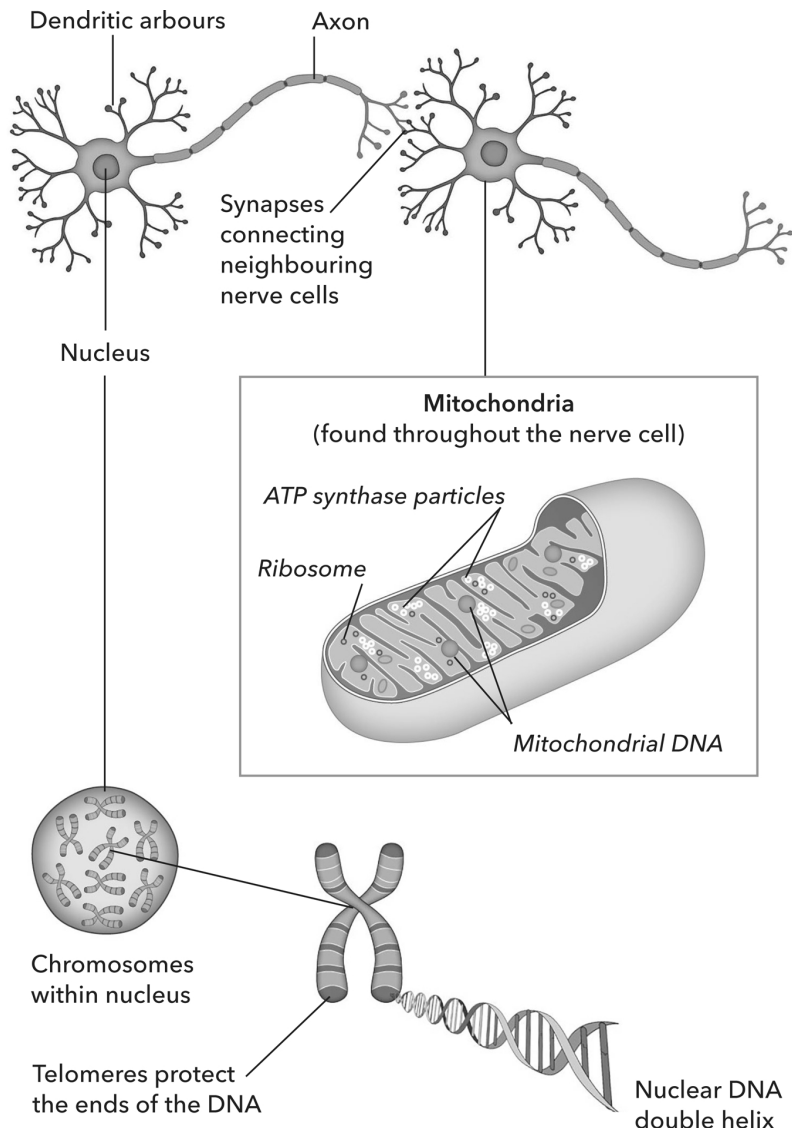
# THE HUMAN BRAIN:

## INNER VIEW



# NERVE CELLS

(86 billion in the human brain)



# BRAIN NETWORKS



## EXECUTIVE NETWORK

*Problem solving, reasoning flexibility and planning – includes the Dorsolateral Prefrontal Cortex and Posterior Parietal Cortex.*



## DEFAULT MODE NETWORK

*Introspection, imagination and dreaming – primarily composed of the Dorsal Medial Prefrontal Cortex, Cingulate Cortex, Precuneus and Angular Gyrus.*



## SALIENCE NETWORK

*Evaluating ideas – involves the Anterior Insula and Anterior Cingulate Cortex.*



## RISK ASSESSMENT NETWORK

*Guiding reward probability and risk analysis – Prefrontal Cortex, Anterior Cingulate Cortex, Amygdala, Striatum and Insula.*

# Prologue

IN 2021, ECONOMIST TIMOTHY WARING AND biologist Zachary Wood of the University of Maine sent shockwaves through the world of biological sciences with their Royal Society publication suggesting that humanity was undergoing a shift in the evolution of individuality. Rather than the fitness of an individual's genes driving a competitive process of selection, they proposed that environmental context was now propelling human development from one generation to the next, at a remarkable pace. In the complex dance of genes and environment referred to by scientists as 'gene-culture coevolution', orthodox opinion had long held that genes were the leader and environment the follower. Having reviewed the latest science behind this vast and crucial biological debate, Waring and Wood concluded: 'If genes hold culture on a leash, culture is [now] dragging them straight off the trail.'<sup>1</sup> They proposed that for the first time in our species' long, slow development, culture (comprising everything that shapes our lived experience, from caregiving, social relations and learning, to diet and exposure to pollution) has a more deterministic influence than genes on our behaviours and outcomes, and that this effect is accelerating.

If you'd told me twenty years ago that humanity was heading for a rapid evolutionary shift, driven not by genes but by environmental factors, I'd have been intrigued but sceptical. My days (and many nights) were spent down in the basement of the Anatomy Building at the University of Cambridge, patiently sitting by a microscope and staring at slices of brain tissue. I was completing my PhD research on connectivity between brain cells, looking at how this neural architecture supports learning and memory, in our perception of the world around us, and how it sometimes goes wrong in cases of psychosis. This was at the height of the genetics-driven revolution in neuroscience, when there was huge excitement about the

world-changing potential of the decoding of the human genome, which had been ongoing throughout my undergraduate studies.

There was also a scientific consensus about the primacy of genes in determining how our individual biology is formed, which was a cornerstone of the case I made in my first book,<sup>2</sup> *The Science of Fate*. At that time, the influence of intertwining genetic and environmental factors on our health, personality and intelligence was increasingly well understood, but to my mind it had been translated into a slightly misleading message: that neuroplasticity meant we could change our outcomes and characteristics at will. I wanted to explain why that wasn't the case. Since then, the science of epigenetics has galloped ahead, establishing that environmental factors can alter genes over the course of an individual's lifetime, so that within one generation outcomes may look very different. As well as the glacial timescale of adaptation I was familiar with through my own research, scientists were observing a real-time shift in how the blueprints for life were changing in response to our supercharged environment.

Studies in genetics continue to enrich the way we understand ourselves and the world, as well as being a vital resource for researchers of every discipline, from biology to sociology. Pioneers in tech-driven biomedical research are teaching AI the language of the genome so it can identify molecules to be developed into treatments for rare diseases, as we will see later in this book. In fact, such AI is able to trawl through the vast data sets of our genetic, protein and microbial make-up. We now have access to staggering amounts of detailed information that, with AI's help, is allowing us to investigate our biology at the most granular level. What this reveals is the extent to which all systems are interconnected. Rather than providing reductive answers to complex questions about individuality and our future prospects, this work is adding layers of sophistication to our knowledge of what makes us human and drives our flourishing.

Scientific understanding evolves as we do and we're currently living through an era-reshaping shift in how we think about the biology of individuality, identity and intelligence. Waring and Wood are far from alone in believing that human beings are undergoing a major evolutionary transition. We seem to be moving away from individual biology shaped primarily by our inherited genes towards a socially integrated mega-group fashioned by the hyper-connected environment we have created with the

help of technology. Is humanity evolving to become more like a colony of ants or hive of bees? Or perhaps more like a computer-aided ‘hive mind’?

This suggestion can feel outlandish, unnerving or exciting, depending on your attitude towards biology and technology, but it is not a fringe viewpoint. The evidence is clear that we have built a digital world so pervasive and powerful in its effects that it constitutes a whole new environment. We can now communicate with each other in unprecedented ways, sharing our views, ideas and perspectives at the simple click of a button. And given that we know that environment and genes are locked together in a perpetual dance, it is entirely predictable that our biology will adapt. As Waring and Wood put it: ‘We speculate that, in the long term<sup>3</sup>, culture will continue to grow in influence over human evolution, until genes become secondary structures that hold human biological design blueprints but are ultimately governed by culture.’ What *is* surprising is the speed and scale of that adaptation. I believe we all need to grasp that our success in this hyper-connected world will be determined not by our understanding of the tech itself but by our ability to behave intelligently in our continually updating environment. The potential rewards are enormous.

This message about evolutionary shifts and leaps in intelligence might feel like a lot to take in at the very beginning of the book, but my intention is not to alarm or overwhelm. Quite the opposite. My suggestion is that we already possess all the cognitive skills we need to flourish in the decades to come. Human beings are exquisitely smart, creative and adaptable. You are more than capable of flexing with the times and deploying your evolved skill set and your personal learning to help you, your family, friends, colleagues and community to thrive. I’ve written this book in order to show you how you can do that, sharing insights from the world’s most cutting-edge cognitive science to illuminate how your amazing brain works, its strengths and its blind spots, so you can feel confident in your ability to navigate this new era of human intelligence.

It might help you to know that human beings have been here before. Between approximately 5,000 and 3,000 years ago, our species went through an evolutionary shift towards collective intelligence brought about by a significant and relatively sudden technology-driven change in our environment. We had established agriculture and created sprawling civilizations, helped by advancements in machinery and technology, and we developed writing. We entered a period characterized by exploration and

cultural exchange. With these changes, our capacity to store information outside our individual brains and to cooperate in larger groups over longer periods was ramping up. Our brains shrank in physical size<sup>4</sup> even as our neural and social networks became more complex. It might seem counter-intuitive that our brain size was diminishing as these changes occurred, but scientists have suggested that when the total cognitive load is divided and delegated among different members of a group with various roles, each individual can be more efficient. A trend towards efficiency of networks takes over and brain size falls. Intelligence goes collective, which in turn drives further biological and cultural changes, as it did with our ancestors all those years ago.

Times may change for the human brain but plenty of crucial things about it haven't altered and remain a constant source of wonder for me. I'm still in awe of the extraordinary processing that takes place in this 1.4kg of soft flesh encased in each of our skulls in which some 86 billion nerve cells are deployed, using chemical and electronic messages to process signals from the outside world and instruct us on how to interact with it. Each nerve cell is linked to up to 10,000 others, forming a circuit board of 86 trillion connections. Electrical signals zip around this infinitely sophisticated network, or connectome, at speeds of up to 120 miles per hour, allowing us to build a model of reality via perception, to form memories, learn from experience, generate emotions, to sense, move, speak and, in a word, live. I continue to be amazed by the brain and the mind it gives rise to and excited at the thought that we may all be standing on the cusp of a leap forward in human intelligence.

A cursory glance at a newsfeed is enough to show us that we're also facing serious challenges. To the ancient foes of war, famine and plague we can now add the climate and ecological emergency, which is fuelling all three. The technologies that are reshaping our environment at warp speed pose risks as well as bringing benefits. A hyper-connected world in which information and ideas flow freely is a thrilling, overwhelming, vulnerable place to live. AI might be the most powerful tool we could possibly have invented for dealing with the challenges that face us, precisely the game-changing intervention we need; but it also poses alarming risks to our integrity and possibly even to our very survival. We need to work together with all hands on deck if we're to stand a chance of tackling these challenges; or rather, we need all brains on deck. Collaboration and

innovation have never been more essential, but in a polarized and individualistic world where we simultaneously know too much and too little, revere a handful of individuals slavishly and overlook millions of others, it can be hard to feel optimistic about our capacity for coming up with a smart response.

In the following pages, I hope to convince you of the reasons to be positive about humanity's potential to thrive in this new era. We already know we're capable of enormous courage, creativity, resilience, resolve, compassion and kindness. These great virtues have their roots in evolved behaviours. They're part of your inheritance and our species' repertoire; we just need to decide to unleash them.

During the writing of this book, I've thought hard about what might equip us to future-proof our brain and thrive in the coming decades. I've looked at many of the skills that make up our staggeringly impressive cognitive toolkit, from empathy and collaboration, creativity and problem-solving, to thinking slowly and over the long term as well as fast and in the moment. I've considered curiosity, resilience, focus, coping with uncertainty, learning, staying flexible and growing wise. I've spoken with many brilliant scientists whose work is expanding what we know about how our brain functions and our mind develops. I've chatted with people about their experiences of how their particular brain shapes their lived experience, from individuals with hyperphantasia (a vastly rich visual imagination) and ADHD to those with schizophrenia and bipolar disorder. All have been supremely generous and open with me, and I am profoundly grateful to them.

A number of things began to crystallize for me, as I applied myself to thinking about how to live a rewarding, happy and successful life in the twenty-first century. Once I had allowed my mind to wander (good for sparking creative insights) before focusing on a particular point, when I'd paused to question my assumptions and sought another opinion to counter my cognitive bias, once I'd rested and thought hard again, I was struck by the recurrence of two themes that run throughout everything I've learned: the importance of physical movement and diversity of thought in fostering human intelligence, on both an individual and a collective level. These concepts crop up in relation to virtually every cognitive skill, task and intervention I've investigated.



Being able to think in many different ways is crucial, and this mental agility depends on a brain that is mobile and vigorous enough to generate new neurons and form new neural pathways. Sustaining this flexibility will be easier if we lean into curiosity and imagination rather than learning by rote. Asking questions, thinking critically and considering whether there are better ways to do things is good for our problem-solving, overall mental health and ability to work with others.

On that last point, humans, as social beings, have evolved to work with each other: collaboration allows ideas to hop from mind to mind, changing in the process, so that pioneering innovation can take place. Getting out into the world in search of new ideas and diverse viewpoints from a whole range of different people is vital, but we need empathy and emotional intelligence to sustain the open and trusting communication that collaboration depends upon.

If we're going to power our brain to do all this metabolically demanding work, and ensure that it stays healthy as we grow older, we would do well to consider what we're feeding it as a power source. Looking after our bioenergetics carefully will mean we have enough energy to sustain all this nimbleness and learning from diverse sources so we can grow wiser without sacrificing flexible thinking.

These concepts – of maintaining mobility at every level, from the cellular to the social, and drawing on as much rich diversity of inputs as possible, from the food we eat to the ideas and opinions we consume – now feel like personal touchstones for the way I make decisions, parent my son and live my life.

When I was peering down a microscope at slices of brain tissue all those years ago, the picture was never static. It wasn't a snapshot of genetic inheritance, frozen in time, but a dance of connectivity in which new connections were constantly forming. Life is dynamic and everything is intimately intertwined at multiple levels, from the connections between your neurons and brain regions to your body's network of organs and how you interact with others. Our minds are capable of transcendent voyages across time and space, connecting the past and the future with the present moment, our ancestors with our descendants. Neuroscience has always filled with me with awe, wonder and optimism. I hope this book will inspire you to feel the same way.

# Emotional Intelligence, Empathy and Collaboration

EMOTIONAL INTELLIGENCE IS THE STARTING POINT for our exploration of what it means to be intelligent in the twenty-first century, because it underpins the successful collaboration between people that will be the hallmark of what's to come. Teamwork has always been crucial to individual survival and humanity's extraordinary success, but its importance has been amplified by the new reality of our hyper-connected environment. As more of us live in cities and our work and social interactions take place online as much as in real life, our ability to connect, get along and communicate with other people will determine our chances of success and happiness. The key cognitive skills that underpin this social aptitude can be grouped under the umbrella of 'emotional intelligence'. They include emotional regulation, which is the ability to manage our own emotions even when under stress, and empathy, or the ability to see things from another person's point of view, to intuit what they are feeling and respond accordingly.

Emotions have been enjoying an extended moment in the neuroscientific spotlight over the last decade. Partly this mirrors an ongoing cultural shift that means it is now far more acceptable to express and speak openly about one's feelings with loved ones, in private and in public and especially on social media. (Some might say that the dominance of emotional discourse in public life has gone too far, to which I would suggest that where that is the case, cultivating emotional intelligence might help.) Alongside this cultural shift, advances in neuroimaging techniques have enabled neuroscientists to study the origin and dispersal of feelings in the human body and brain, as we shall see.

This shift towards taking emotions more seriously is still very new. There is a long tradition in Western thought of regarding feelings as messy and unreliable, particularly since the humanist revolution got under way and natural science and philosophy coalesced around the idea that reason must rule over emotion. One of the unfortunate legacies of René Descartes' famous encapsulation of mind–body dualism ('I think therefore I am') is the way in which the body's wisdom has been consistently overlooked ever since, by scientists and philosophers alike. The mind's superiority was assumed to be obvious. It is only recently that this attitude has begun to change as the result of scientists exploring how our thinking is supported by the gut, heart and peripheral nervous system as well as the brain. As we will discover, recent breakthroughs in understanding the impact of our interoceptive ability, or intuition, and gut microbiome on our individual and collective behaviours have led to a new science of emotions. And this is shedding a light on the intertwined relationship between body and mind, feeling and thought within each individual and in how we relate to each other. Emotions are no longer considered less important than our so-called 'higher faculties'. They are part and parcel of the unique ecosystem that makes up every person, group and society. Unless we know how to work with our emotions harmoniously, we will be missing out on a large part of our evolved skill set.

Many of us grew up with the belief that feelings were the opposite of thoughts and in direct tension with intelligence. Emotions, we were told, made us sloppy, weak, irrational, hysterical. Empathy and emotional intelligence were overlooked in scientific studies, which focused instead on memory, learning, pattern recognition or task-switching ability. Daniel Goleman's bestselling book<sup>[1](#)</sup> *Emotional Intelligence*, published in 1995, was one of the first to advance the idea that emotions were as crucial to success as a high IQ or strong working memory. Since then, the concept has been widely discussed and accepted. Even so, until the neuroscience boom of the past decade it remained a slightly nebulous notion, easier to observe in behaviour than analyse at a biological level. That changed with the advances in neuro-imaging techniques such as MRI scans, which allowed scientists to explore a rich seam of new information, leading to a better understanding of consciousness and free will, our species' trajectory and how we can best protect the very essence of ourselves – our brains – in the future. It has become very clear that a crucial element in successful

outcomes for both individuals and groups is the ability to regulate emotions and empathize with other people. Such skills underpin collaboration, creativity and consensus-building, as well as ongoing learning and better problem-solving, and they even offer a degree of protection against neurodegeneration in older age.

As we grapple with the challenges posed by AI, emotions may offer us a way in which to cultivate a unique human advantage. New technologies do demonstrate some semblance of collaboration – think of the ecosystem of Wikipedia bots working 24/7 on iterations of edits to keep the online encyclopedia current. (The Wiki bots also display a rather endearing *lack* of emotional intelligence since they fight<sup>2</sup>, hold grudges and sabotage each other's tasks, making them highly relatable to anyone who's ever worked in an office.) In 2017, there was a stir when Facebook's AI bots were shut down after they started negotiating among themselves in a new language they'd developed that was largely incomprehensible to humans.<sup>3</sup> There are also bots that display a semblance of empathy. In 2023, for example, a study revealed that chatbots are just as accurate and far more empathetic than doctors<sup>4</sup> when answering routine questions in short interactions with patients. (Admittedly, overstretched medical professionals are not often held up as paragons of emotional intelligence.) But without a biological body of its own, AI may never be able to truly feel emotions or develop advanced emotional intelligence; and for now, at least, it is limited in this respect. Rather than fretting about AI's possible advantages, it would make better sense to lean into this key human skill, so fundamental to our past successes, and use it to future-proof ourselves and our children. Honing one's emotional intelligence is the foundational task for anybody who wants to train to be cognitively fit in the twenty-first century.

## Your feelings can dial your intelligence up – or down

In order to grasp how our feelings can make us smarter – but also risk making us much stupider – it helps to understand how they come about. Emotions are the result of information-processing that takes place without our conscious awareness. By the time you decide you are happy because you love this particular person or have found the place in the world where

you can truly relax, your brain and nervous system have done an enormous amount of work responding to, for example, a sexual encounter or a good meal out on a sunny day. A positive stimulus of that kind activates the reward pathway of your brain, triggers a dopamine release and electrically stimulates your nucleus accumbens, a region encompassing two small, round areas buried deep in the middle of the brain that arose early in our evolution to help us survive by creating feelings of motivation, reward and pleasure. High-calorie food, sex and physical exercise activate this region, causing pleasurable feelings to flood the body and making you more likely to repeat the behaviour – a bonus for your individual well-being, and the driving force behind our ancestors’ survival and reproductive success. Our conscious awareness arrives late to this party, scrambling to label the sensations as ‘happiness’. Or ‘romantic love’. Or some other label derived from feelings, memories, meaning-making stories and all the other complex perceptions your brain can conjure up.

At the other end of the spectrum are feelings of fear, which help to protect us from danger. They arise from the activation of the amygdala (two small, almond-shaped structures buried in the brain above the ears), directing a hormonal cascade including cortisol and adrenaline that prepares our body for fight or flight. These negative feelings hyper-charge emotional memories by connecting the amygdala to other areas of the brain. Traumatic experiences direct the construction of new connections between the amygdala and the neighbouring hippocampus (a seahorse-shaped structure in the middle of the brain involved in memory formation and controlling how we navigate the space around us) and the prefrontal cortex (the region behind the forehead involved in higher-level decision-making, reasoning and planning). The protective purpose of this experience-led construction of new connections between brain regions is to ensure that we will remember if a similar situation arises again and take steps to avoid or deal with it. (For a map showing all the regions of the brain covered in the book, see [page viii](#).)

As with positive emotions, the sensations produced by negative stimuli are interpreted by our conscious mind in varying ways depending on context. We might call a response of this kind ‘fear’ or ‘dread’ if an aggressive dog runs towards our child in the park, or we suddenly hear the music from *Jaws*. A similar sensation as we stand up to give a presentation

before a large audience, or step out of a plane to fulfil our lifelong dream of skydiving, might be labelled ‘nerves’ or even ‘excitement’.

Our emotional responses are far more nuanced and varied than these simple polar opposites, of course, but the principle holds that emotions are information sent via signals that erupt from our body and are then analysed by our mind. They are the outputs of distinct electrical signatures in our brain, converging to guide our behaviour and influence our decision-making. Our personal signature style of emotional response is shaped to some extent by the genes we were given by our parents, which is part of the reason why some families seem predisposed to anxiety rather than optimism, for example. Our emotional states are also governed by our environment, our situation and even the people we share them with, thanks to a biological phenomenon known as ‘emotional contagion’ that causes us to subconsciously pick up on and mirror the emotional responses of those around us.

Beyond their impact on our mood, emotions have a huge effect on our decision-making and problem-solving. When we’re feeling frightened, our whole perspective on reality changes. Negativity bias kicks in and we see everything and everyone as a potential threat, whether it’s a dark shadow on a street corner or merely someone challenging our opinion in a meeting. Our conscious awareness can’t tell the difference, and as we switch subconsciously into fight or flight mode our thinking narrows. The bigger picture (along with curiosity, empathy and creativity) vanishes as our biases kick in. Our executive functioning switches off so that we can deal with the urgent problem, even if it really isn’t that urgent at all. And all this is happening unawares, without any decision from us. The first we know about it might be a sick feeling in our stomach, swiftly followed by anger.

This has consequences. Individuals and groups that habitually operate from a place of fear have been shown to be more closed-minded, more biased and more prone to being influenced by populism and propaganda. They are less likely to look for solutions to problems or participate in groups that are successful in getting results. Fear can cut us off from helpful information and collaboration, making it harder to be effective and driving us towards anxiety, stress and poor mental health.

Fortunately, it is possible to get more comfortable with fear, lean into curiosity and reap the benefits to our intelligence this can bring. But because fear feels unpleasant, we must train ourselves to manage it, which

depends on noticing it in the first place and then evaluating what it (or any of our emotions) is telling us. If we dismiss or ignore this valuable source of information, we are turning away from potential and opportunity, which is why it's crucial to practise tuning into our feelings by bringing awareness to them, slowing down our judgements so that we make better decisions while simultaneously soothing our distress or agitation. This whole sequence of actions, which together add up to emotional regulation, begins with interoception, our sixth sense – an ability to detect signals from within the body that scientists believe is the basis for intuition.

Professor Sarah Garfinkel at University College London<sup>5</sup> and her team have undertaken pioneering research into the biological mechanisms that underpin interoception. They have also developed exercises that help people tap into their intuition by increasing their sensitivity to the body's internal signals, in particular the heartbeat. Interoception appears to depend on the ability to pick up on such cues, and it turns out that we can all get better at it. Sarah asked her study participants to do some star jumps or a few burpees, anything to briefly get their heart rate up, sending oxygen rushing around the body and up to hungry brain cells. She then invited them to relax, listen to and make a note of their heart rate. Having carried out just six sessions of this so-called ADIE (Aligning Dimensions of Interoceptive Experience) exercise training, participants became more sensitive to their heart rate, and more accurate in noting it. Such strengthened interoceptive ability is now shown to track alongside lower anxiety and the ability to make more rational decisions.<sup>6</sup>

Sarah and others working in this new area are gathering compelling data that suggests how tapping into our interoceptive ability can enable us to access information more accurately from the world around us. This includes the signals that other people are subconsciously communicating – whether via their facial expressions, movements or even through the chemicals in their sweat – that our conscious mind would otherwise miss. The benefits for confident and informed decision-making have been demonstrated in many different groups, including financial traders<sup>7</sup>, whose individual interoceptive ability predicted their trading success. Those traders with better baseline ability (as measured by the heartbeat detection test) made greater profits. They were able to take better decisions on the busy trading floor despite the uncertainty, stress and chaos of the situation.

Interoception depends on the transfer of information via the vagus nerve, a thick bundle of nerve cells that runs between vital organs (such as the heart and gut) and helps to transmit signals between them and the brain. It travels up to the brainstem, and from there sends signals on to the insula (a region of brain tissue above the amygdala and hippocampus). The insula has traditionally been overlooked in neurophysiology, but it is increasingly being appreciated for its crucial role in our ability to recognize and process the emotions of others and ultimately to empathize with them. It links to regions across the brain, including the amygdala, hippocampus and prefrontal cortex. This highly sophisticated whole body/brain network supports our internal sixth sense and with it the foundation of emotional intelligence that underpins emotional regulation, intuition, insight, empathy and all the social skills on which so much of our success and well-being depend.

When we practise flexing our interoceptive ability, we become better at thinking not just with our brain but also in processing the plethora of information from the outside world that is stored in the peripheral nervous system of our heart and gut. This makes it easier to pick up on how we're doing and what we're thinking, but also how other people are feeling and thinking. It means we can access their knowledge, empathize with their situation and collaborate more effectively. Strikingly, Sarah and her team have found that interoceptive training is particularly beneficial for individuals diagnosed with autism<sup>8</sup>, a condition that can make it harder for them to recognize complex emotions in themselves and others, and to process and manage their emotions. Interoceptive training could benefit everyone: it's a quick, easy and effective intervention to boost one of the most important cognitive skills. For a simple exercise to help boost your own interoception, see the exercises at the end of this chapter.

## Empathy makes you happier and kinder as well as smarter

For neuroscientists, empathy is not some nebulous nice-to-have but a measurable trait. We distinguish between 'cognitive empathy', which is the ability to recognize another person's thoughts and feelings, and 'affective



empathy', the capacity to respond with an appropriate emotion to the thoughts and feelings that somebody else is experiencing.

Higher empathetic ability is linked to feeling more satisfied in relationships and happier in life.<sup>9</sup> Studies have also demonstrated that it reduces the likelihood of people being misled by false information and supports them in creating a more accurate representation of the world.<sup>10</sup> In other words, it makes us both happier and smarter. So what factors influence the development of this crucial trait?

Twenty-one years ago, a team of scientists at the University of Cambridge led by Professor Sir Simon Baron-Cohen set out to answer this question. They developed the Empathy Quotient (EQ) scale, a brief self-reported measure of empathy that scored people's EQ on a sliding scale. The initial study showed that some individuals are more empathetic than others<sup>11</sup> and that, on average, autistic people score lower on the EQ scale, especially on the cognitive empathy element. (This finding was subsequently confirmed in a large online study of 36,000 autistic people and 600,000 controls.<sup>12</sup> )

Having established that empathy was measurable and varied between individuals, the next step was to account for what caused the variation. To what extent were genes involved? The team discovered that EQ appeared to have a heritability rate of around 10 per cent,<sup>13</sup> although other scientists, who used the method of comparing identical and non-identical twins,<sup>14</sup> have found empathy heritability rates of between 26 and 48 per cent. Taken together, these figures suggest that while part of people's empathetic ability is due to genetics, at least 52 per cent, and possibly much more, is not. Non-genetic factors that might significantly influence the development of empathy include the hormones a baby was exposed to before birth and the way they were cared for during infancy and early childhood. (Empathy is one of those core behaviours that we learn throughout childhood and contributes to various childhood developmental milestones. Three-year-olds aren't very good at it, as you will know if you've ever encouraged one to share their toys; ten-year-olds are much better. While it can be nurtured throughout a lifetime, the environmental factors influencing its initial development are unsurprisingly heavily influenced by childhood interactions.) In 2023, Simon and his team followed up their earlier studies

by testing over 1 million people<sup>15</sup> globally, which confirmed that women are, on average, more empathetic than men. This difference was seen on a performance test of empathy across cultures, and again could reflect both social and biological factors.

If social factors play such a large role in the development of empathy, surely it is possible to boost our personal abilities by exercising these skills? Can we consciously curate our environment to improve our empathetic ability? There are some interesting studies in this area that have focused on autistic people, who are generally less empathetic than a control group, as we've seen. Dr Sonja Simpraga and Professor Klaus Linkenkaer-Hansen from Vrije Universiteit Amsterdam wanted to investigate how autistic people spend their unstructured thinking time<sup>16</sup>, or 'mind-wandering', the term cognitive scientists use for getting lost in thought and imagining different scenarios. It's now known to be a primer for creativity, as we will see in the next chapter, and also helps to boost empathy. The researchers found that autistic individuals had significantly fewer 'theory of mind' thoughts than neurotypical people. ('Theory of mind' is a term used by psychologists and philosophers to describe the capacity to grasp that another person has a different mental and emotional state from your own. It's a cornerstone of being able to understand other people.) They were more likely to spend their mind-wandering time having internal monologues about very specific aspects of their environment. They spent less time thinking of others, imagining themselves in their situation or thinking from their perspective.

Given the advantage conferred by being able to empathize, scientists began to wonder whether autistic people could learn to be more empathetic. If trained to think about other people, would their general EQ level improve? In 2018, a study examined exactly this<sup>17</sup> – whether theory of mind training could improve empathy in autistic children aged between eight and thirteen. It turned out that it absolutely could. A one-hour session once a week for just eight weeks was all it took for the children to show significantly higher levels of empathetic responsiveness, defying assumptions about autistic people's abilities in this area. As we will see time and time again throughout this book, the human brain is incredibly resourceful, finding work-arounds that allow it to hit goals, whatever the individual's cognitive resources.

There is plenty of scope for all of us to enhance our emotional intelligence skills later in life. Stanford University psychology professor Jamil Zaki believes that empathy is not a fixed trait<sup>18</sup> but a skill that can be nurtured. His research can be distilled into some easy exercises. The first (pleasingly counter-intuitively) is to practise self-compassion, which we'll look at in more detail at the end of the chapter. Second is to take time to notice and praise empathy in others, which can have a profound impact on group dynamics as a kindness-specific version of emotional contagion ripples out. Third is to do one small thing every day that involves thinking of other people, especially if you are feeling rushed or worried. Whether it's picking up a coffee for a friend who seems tired or sending a quick message to check in on a family member, performing these tiny acts – especially at moments when we feel like we can't – can be energizing, enlivening and definitely much better for us than turning inwards under pressure.

Jamil also advocates seeking out conversation with someone with whom you disagree, but, crucially, ditching argument or debate and simply telling your respective stories about how you formed your opinion on a particular issue. Give each other a set amount of time to listen without interruption. This increases the likelihood that you will both gain an empathetic understanding of why you think differently.

As well as behaviour-based practices, it seems that we can also improve our emotional intelligence through our diet. There's emerging evidence that a flourishing gut microbiome is associated with higher empathetic abilities while impaired gut health has been linked to problems with emotional regulation, intuition and relational difficulties in autistic children, as I learned in 2024 when I met Dr James Kinross from Imperial College London.<sup>19</sup> We were at the Hay Festival, where he was talking about his book *Dark Matter: The New Science of the Microbiome*. A number of studies have shown that children diagnosed with autism<sup>20</sup> often have altered gut microbiota, perhaps unsurprisingly given that autism is often associated with sensory constraints that affect the types and variety of foods that can be consumed. But what's really striking is what happens if such children receive a faecal-matter transplant (FMT) from someone who does eat a varied diet and has a healthy microbiome. Transferring tiny amounts of human waste from person to person might sound odd but it's been shown to be safe and effective if done carefully. Jing Zhang and colleagues at the

General Hospital<sup>21</sup> in Beijing reviewed the data on the practice from inception (the earliest peer-reviewed trial on this was published in 2017) through to October 2022, a total of five studies. They concluded that although more studies were required, FMT does appear to significantly improve a breadth of symptoms associated with autism in children. It's an admittedly messier way of achieving the same effect as prescribing probiotics, which as one recent review of their use in treating autism<sup>22</sup> showed, can be helpful for the recipient's gut, reduce inflammation and improve behavioural symptoms, including sleep issues, defiant or destructive behaviour, anxiety, self-injury, lack of expressive language and social impairment. While probiotics and a healthy varied diet full of fruit and vegetables definitely seem a more appealing route than poo transfers, the weight of evidence suggests that taking care of our gut health can deliver a serious boost to emotional intelligence for everyone.

Our gut microbiome also appears to play a pivotal role in our levels of altruism – the impulse to be generous to others even if it carries a cost or a risk to ourselves. A key element of what scientists call 'prosocial behaviour', altruism contributes to collaboration as well as ethical behaviours and what we might term 'morality'. Hilke Plassmann, Professor of Decision Neuroscience at INSEAD and Sorbonne University, carried out a study of a hundred healthy volunteers<sup>23</sup> that were randomly assigned to one of two groups: half took a supplement containing both pre- and probiotics for seven weeks and half received a placebo. Plassmann's team assessed their behaviours using the famous 'ultimatum game' at the beginning and end of the seven-week period. In this standard test of prosocial behaviour, one player is given a sum of money they must split (fairly or unfairly) with a second player, who is free to decline the offer if they deem it insufficient. In that case, neither player receives any money. Refusing the sum of money is equivalent to what psychologists call 'altruistic punishment', the impulse to punish others when a situation is perceived as unfair. For the second player, restoring equality (no one receives any money) can feel more important than obtaining money if that amount is perceived as unjustly small. Results indicated that the group that received the supplements was much more inclined to reject unequal offers at the end of the seven weeks. They were willing to sacrifice their own

reward in favour of making a stand for fairness, even when the money split was only slightly unbalanced.

This may only be a small study but, nevertheless, I find its results profoundly interesting. Our urge for parity, even with a total stranger and even if it means receiving less ourselves, feels like a core strand of human ethics. The fact that it can be swayed by a healthy commune of microbes in our intestine apparently releasing neurotransmitters that help us to help others, amazes me. Gut health is in fact taking on a pivotal role in shaping our overall cognitive fitness for the twenty-first century, as we will discover in [Chapter 5](#), when we explore the impact of diet on how we see and interact with the world.

## Emotional intelligence lies at the root of collaboration

The altruistic urge makes sense from an evolutionary perspective when you remember that human beings are profoundly social animals, highly dependent on other members of a group and motivated to seek out the safety of a community and work hard to avoid the dangers of isolation. Any behaviour that helps us maintain our social success is therefore highly adaptive and has been honed by evolution as part of our most fundamental cognitive toolkit. Being able to grasp that other people have valid points of view and feelings and then responding appropriately underpins the social skills that have powered human development and driven our spectacular achievements, from the building of great libraries and temples to crowdfunded, crowd-written Wikipedia entries or the mutual-aid networks set up during the COVID-19 pandemic.

Our so-called ‘social brain’ may have been key to our evolutionary success, but it’s not unique to humans. It’s not even unique to mammals. Ants, fish and birds have all evolved something similar – albeit on a simpler scale. The *Drosophila* fruit fly might not be well known for its sociality, for example, but it will interact for reasons other than mating: it shares information across networks about parasite infections or tips on egg-laying sites, and hangs out with others rather than staying in isolation. In 2020, Professor Yan Zhu of the Chinese Academy of Sciences in Beijing and his team conducted a series of ingenious genetic and surgical tests on fruit

flies<sup>24</sup> to investigate the neurochemical mechanisms that motivated them to be social. It turned out that they, like us, had social circuitry that was fuelled by serotonin to make them seek out the company of their fellow flies. Moving up the evolutionary scale, prairie voles are both social and capable of forming a long-lasting, monogamous bond<sup>25</sup> with their life partner, often to the exclusion of other sexual attachments. The social circuitry of prairie voles runs, like ours, not only on serotonin but also dopamine, associated with pleasure and reward, and oxytocin, which has been linked to pair-bonding. The degree of conservation across evolution of these basic circuits is striking. Whether you're a fruit fly, a prairie vole or a human being, it looks very much as if your flourishing depends on prosocial behaviours and the brain circuits that support them.

In humans, this conserved social brain connects areas linked to decision-making and the processing of emotions. The basic circuits seem to have developed much further to help us form deep bonds with one another, find joy in shared experiences, deploy and enjoy humour, empathize and care for each other: all traits and behaviours that have further boosted our capability for group work and community-building. (Interestingly, these circuits show altered activity in the brains of autistic children,<sup>26</sup> which for some individuals is characterized by finding it hard to make friends or preferring to be on your own.)

The focus of the recent neuroscientific work on empathy, social bonding and altruism as key pillars of our evolutionary success is in direct contrast to the classic psychological view that prevailed in the decades after the Second World War. Between the 1950s and 1970s, behavioural psychology produced the original bystander-effect studies<sup>27</sup> and the notorious Zimbardo prisoner experiment,<sup>28</sup> which seemed to demonstrate that individuals were motivated by self-interest, willing to inflict pain on others and follow orders blindly, and indifferent to the plight of other people. These experiments were conducted at a time when the scientists devising them were influenced – unsurprisingly – by a belief that our ‘evil’ side lay just below the thin veneer of morality and altruism that made up our civilized surface. Reporters and psychologists alike encouraged the view that human beings were essentially callous and selfish and emotions were untrustworthy. Recent research is much more hopeful, showing that those original studies were flawed<sup>29</sup> and very much a product of their time, and



finding abundant evidence instead for the traits of heroism and altruism, compassion and empathy. The number of annual scientific publications<sup>30</sup> that include the terms ‘prosocial’ or ‘altruism’ in their title, abstract or keywords has increased exponentially from almost none in 1970 to around 1,500 publications for each term in 2021.

Science, like every other human discipline, is framed by its cultural and social context. All intelligent endeavour is subject to biases at worst and the preoccupations of its historical moment at best. I don’t want to suggest that humans are altruistic in any monolithic or simple way, only to point out that we, like most other species on this planet, did not evolve to live, work or think alone. We are social and emotional as well as rational and analytical, and the skills that support these different modes of behaviour are all critical and all connected.

This could not have been more starkly demonstrated than during the COVID-19 pandemic. We already knew that loneliness was one of the biggest threats to our physical health, equivalent in risk to smoking fifteen cigarettes or having more than six alcoholic drinks a day.<sup>31</sup> But what also became apparent was that the isolation measures put in place by governments resulted not only in a decline in physical and mental health as social contact was diminished, but in our brain power actually dimming. Joanne Ingram, Senior Lecturer in Psychology at the University of the West of Scotland, was one of the first researchers to demonstrate this. In 2021, she showed that cognitive scores, as measured by online tests of attention, memory, decision-making, time-estimation and learning, were significantly lower during periods of enforced isolation<sup>32</sup> in lockdowns, only improving when social interaction was restored – which occurred more slowly in people who carried on shielding. The message was clear: our physical, mental and intellectual health rely on a sense of connection with others – being part of a team.

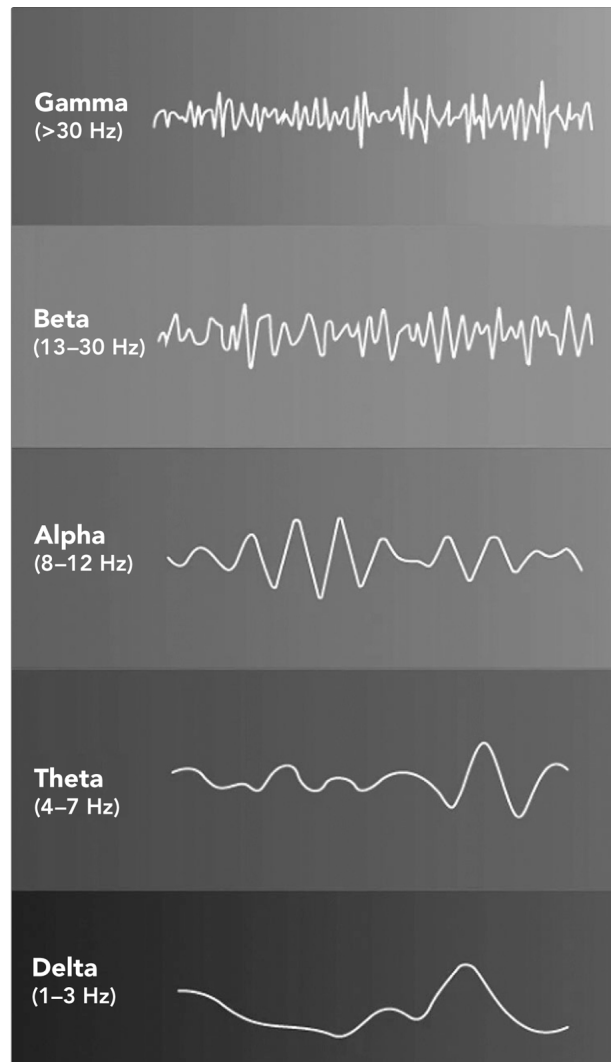
Connectivity is key to brain health and intelligence. Ever since scientists have been able to observe the conscious brain in action, they’ve been looking for clues as to how we foster resilience and build environments that allow creativity and innovation to flourish. There is a wealth of information from this type of study: a method called EEG (electroencephalography, a non-invasive technique which involves placing over fifty electrodes at specific points on the scalp) allows scientists to analyse electrical

oscillations travelling across the brain as an individual thinks, feels and remembers. These electrical currents are formed by the nerve cells pumping charged potassium and sodium ions in and out of the cell membrane, creating a fizz of electrical activity that moves along one nerve cell to activate the next cell in the circuit. It's this electrical connectivity that underpins every brain function, from the perception that creates our sense of reality to our moods and decisions about how to interact with the world.

Different frequencies of brain waves are associated with different cognitive functions (as shown in the image on [page 28](#)). Alpha waves, for example, are the slowest frequency of electrical oscillation in the awake brain and are associated with calm, creative thinking. They can be hampered by stress but are fostered by spending time in the natural world, which helps to explain why so many of us feel clearer-headed and more relaxed when we're walking in a forest or swimming in a river. Gamma waves, on the other hand, are the fastest electrical oscillations and help to integrate information from disparate regions, promoting joined-up thinking across the whole brain. Studies have shown that gamma waves can be stimulated through meditation.<sup>33</sup> With a level of oscillation that falls in the middle of these 'awake' brain waves, beta waves are associated with alert, focused, concentrated thought, and can be induced through physical exercise<sup>34</sup>. Slower still than alpha waves, theta waves occur during light sleep, meditation or hypnosis, and are associated with insight and creativity. Delta waves, the slowest type of brain wave, predominate when we enter deep, dreamless sleep and appear crucial for physical recovery and cellular repair.

Enhancing gamma, alpha and theta waves, in particular, has been linked to boosting our capacity to think more collaboratively and creatively. When we engage in activities that support these particular brain waves, we get better at focusing less on immediate gratification and individual threats in the here and now, which in turn helps us to open our minds to consider the longer-term and wider view. Our future selves, not to mention future generations, will have reason to be grateful. We will explore insight and creativity in greater detail in the next chapter, but for now I want to focus on how our brain waves change as we productively collaborate and work with others.





**Measurements of the oscillations made by the different types of electrical waves across the brain, from the fastest (gamma) to the slowest (delta), each associated with specific types of brain activity:**

- Gamma – heightened perception, integrating information across the entire connectome
- Beta – alertness, concentration
- Alpha – relaxed creativity
- Theta – light sleep, dreaming, insight, creativity
- Delta – deep, dreamless sleep, loss of bodily awareness, essential for cellular repair.

Connectivity is as crucial for different brains to work effectively together as it is for the regions in an individual's brain to interact with each other. Brain synchronicity supports the emotional intelligence and mutual understanding that drive collaboration across teams and groups. And when we examine what happens to people's brains as they work alongside each other, we see truly magical things.

In 2024, a study led by Tzipi Horowitz-Kraus at the Technion (Israel Institute of Technology) in Haifa analysed the brains of parents and their children (who were around ten years old) as they lay in a brain-scanning machine while stories were read to them. The team used fMRI (functional magnetic resonance imaging) to examine how oxygen levels changed as the participants listened. (Fluctuating oxygen levels are a proxy for the metabolically demanding process of electrical activity firing across circuits around the brain. Differing levels show up as different-coloured patches in the image on the fMRI scanner's screen, lighting up as a brain region becomes active.) The researchers discovered that parents' and their children's brains reacted in extremely similar ways to the stimuli of the story; so similar, in fact, that the team could predict from the brain scans who was biologically related to whom. The sequence of circuits that were metabolically active was unique to each pair, adding up to the neural equivalent of a fingerprint.<sup>35</sup> The scientists reasoned that the years spent sharing stories, experiences and interpretations had created mutual perceptions, resulting in a synchronized response even when an entirely new story was introduced.

Other studies have enabled us to understand more about the social factors that affect brain synchronicity, such as the relation between people participating and the type of activity or stimulus they were engaged with. In her investigation, Kerstin Konrad, Professor of Clinical Child Neuropsychology at RWTH Aachen University, Germany, used functional near-infrared spectroscopy (fNIRS), a technique that bridges fMRI and EEG. Electrodes were placed on participants' scalps, this time to measure changes in oxygenated haemoglobin concentrations in the brain by analysing how different areas close to the surface absorb or scatter the near-infrared light. This revealed that brain synchronicity occurred when parent and child were collaborating on a task,<sup>36</sup> but not when a stranger and child were collaborating, and not when people were competing rather than working together. She focused on two specific areas of the brain, the

dorsolateral prefrontal and frontopolar cortex, regions behind the forehead involved in cognitive control over emotions and higher cognitive functions such as planning, problem-solving and reasoning. Her study also revealed that the higher the brain synchronicity between parent and child, the better they did at the collaborative task, and that this was also linked to their emotional connection and the child's ability to emotionally regulate. Kerstin believes that this brain-to-brain synchrony may represent an underlying neural mechanism for emotional connection between parent and child, which paves the way for the child's development of healthy emotional regulation.

In 2024, Zhuo Rachel Han, Psychology Professor at Beijing Normal University, and her colleagues used fNIRS to analyse the brains of eighty-eight sets of parents and their children (who were around eight years old) during a drawing-based collaborative task. They too found brain synchrony<sup>37</sup> in the dorsolateral prefrontal cortex, but they also found it in another region – the temporo-parietal area, which is further towards the back of the brain and which collects and integrates information from the external environment and from within the body. It has been associated with a wide range of emotionally intelligent behaviours that have huge implications for how we form relations with others, from theory of mind to morality. The researchers emphasized the role of supportive, warm and autonomous parenting in fully developing this area of a child's brain, so that they can go on to empathize and collaborate with others. These skills are doubtless crucial for the development of a baby's brain but also for our ability to align our perceptions at any age – including as we grow older and deal with the debilitating impacts of being socially isolated. An article published in 2022 in the journal *Neurology*<sup>38</sup>, for example, drew on a study demonstrating that social isolation in older adults was associated with a 26 per cent increase in the risk of dementia. We will be looking at the links between our social lives and our long-term brain health in more detail in the last two chapters of this book.

These groundbreaking studies help us to understand how both the emotional bond with and physical presence of others have a physiological impact on our ability to learn and emotionally respond to and process information, creating a shared reality as we go through life. The results serve as a reminder to value the importance of collaboration rather than

competition, whether we're working as a team in the office or navigating family dynamics at home.

Brain synchronicity is not confined to parents and children or even relatives and friends who have shared experiences. It may take longer for our brain waves to sync with a stranger's, but it can and does happen, and scientists have begun to figure out how. Activities that require collaboration rather than competition, a shared focus, teamwork and open communication seem to boost it. Researchers can see the frequency of electrical waves converging between a group of people when they work together on a task, which provides a massive boost to everyone's ability to learn, build consensus and improve cooperation. An effective group is already halfway to forming a human super-brain.

Perhaps we intuitively knew this, since we talk about people being 'attuned to one another' or 'in sync'; but scientific studies clearly demonstrate it to be measurably true. Direct eye contact,<sup>39</sup> a positive mood<sup>40</sup> and emotional closeness help the process, as does coordinated physical activity such as playing music, dancing or singing as a group (which is why I often take C-suite business leaders<sup>41</sup> out to sing together as part of our team-building exercises on awaydays). There seems to be a link between the level of brain synchronicity a person exhibits and a decreased risk of neurodegeneration in older age. This ties in with evidence from public-health studies<sup>42</sup> that suggests interacting with others helps protect the brain against dementia – an important finding considering that we are living longer but more of us face the prospect of neurodegeneration in old age.

Studies on synchronicity<sup>43</sup> also give interesting answers to the question of whose brain is setting the pace. Although it's often a person considered charismatic by their peers who initially takes the lead on phasing brain synchronicity, different individuals step into the role of leader as the interactions evolve, taking it in turns to lead and then falling into step with others as the situation changes. Much as starlings in a murmuration or geese on a migratory flight synchronize thinking and movement and take turns to orchestrate the collective dance, so too do humans. And the better we are at this, both as individuals and groups, the easier we will find it to harness the different perspectives of the group and solve problems with the grace and style of those swooping starlings.

# Empathy is rocket fuel for an evolutionary shift

We have barely begun to understand how much potential is held within teams and networks of people when they're collaborating effectively, but it is increasingly clear that intelligence in the context of a mega-group rests on our capacity to harness emotional intelligence and develop empathy with others. Many studies have demonstrated that a diverse group of people come up with better solutions to problems than any individual, however expert, working alone. But studies have also shown that a group's ability to access and implement their collective intelligence depends on their capacity to listen to one another with open minds. It requires social norms around communication to support turn-taking in conversation, active listening, curiosity and willingness to learn. When this is all in place, human beings come up with great ideas, decisions and solutions. The alternative is plain to see in any Twitter/X pile-on: polarization, echo chambers and unchecked bias.

Emotional intelligence and empathy are the key skills that will mark out smart and successful individuals over the next decade and beyond, but they are precisely the skills that depend on us not feeling afraid of our new reality. The difference between being overwhelmed by fear of interacting with other people and embracing new technology, and being open to them, is the difference between a future-proof brain and flourishing future, and their opposite. It's time for all of us to embrace this evolution with curiosity and excitement. And if that still seems a little daunting at this early stage in the book, we could do much worse than start by learning to regulate our emotions through meditation, boost our capacity for brain synchronization by taking up dancing or singing in a choir, and soothe any stress spikes by popping out for a walk in the park or countryside at lunchtime.

## **|EXERCISES|**

A brain fit for the 21st century is ... emotionally regulated and empathetic

- Take time every day to listen to the collective wisdom stored in your body from interacting with the environment. This intuition, also referred to as

embodied cognition or interoceptive ability, is our superpower. Listen to your heartbeat and acknowledge it, morning and evening. If you struggle to tune into it, do thirty seconds of aerobic exercise such as burpees or star jumps. Your strong, fast heartbeats should be easier to pick up afterwards.

- Look people directly in the eye when you're talking to them. Try group activities such as singing or exercising together. This can help us to learn from others, build consensus and work innovatively by boosting brain synchronicity among the team and creating a proto 'hive mind'.

- Boost your capacity for empathy with others by practising self-compassion. Think about a problem you're struggling with and reflect on how it makes you feel. Notice whether there is a critical voice that pops up in your head, and, if so, the language it uses. Then imagine a friend coming to you with the same problem and asking for advice or support. How would you respond to them? Consider the two responses. Are you kinder, less critical and more compassionate when thinking about your friend than about yourself? If so, try to consider the problem and speak with yourself more as you would with your friend. This takes practice. If you find it tricky, try speaking to yourself aloud. If that makes you feel silly, treat those feelings as an opportunity to acknowledge your uncomfortable emotions!

## Imagination, Creativity and Flexibility

YOU MAY BE A CREATIVE GENIUS with multiple intellectual patents and a Nobel Prize to your name, but whether you are or not is immaterial: I know for sure that your mind is fizzing with ideas. Human beings are innately creative problem-solvers. As a rule, we love novel ideas and elegant solutions and delight in expressing our unique perspective on the world. From a neuroscientist's point of view, the difference between a Wolfgang Amadeus Mozart or an Ada Lovelace and the rest of us is only one of slight degree. We may not have our names recorded by history but we're all capable of questioning, speculating, conjuring up the far-off past or imagining an unknowable future. The healthy human mind is brilliant at feeling its way into alternative realities and testing ideas in highly abstract and original ways. We all do it instinctively, from early childhood.

In this chapter we will build on what we've just learned about the foundational importance of our emotions and ability to empathize, by examining another core behaviour that contributes to our individual and collective success: the capacity to innovate through creativity. I'm not talking about being artistically gifted or agile in business, but about something more fundamental – the way human beings constantly seek novel solutions to micro-problems. You doubtless know yourself the feeling of satisfaction that accompanies the fizz of a fruitful idea or the rewarding sense of accomplishment that you get when you come up with a new way of doing things. Every time you do something of this kind – from inventing a rhyme to distract your irritable toddler or thinking of the precise word to describe a toxic date, to sketching your vision for a project at work or coming up with a clever storage system for clutter at home – you are drawing on your mind's capacity to operate in a highly abstract realm of

ideas, imagination, and visual and linguistic conjuring. In short, you are being creative.

But what exactly happens in the brain to underpin this process? Can we break it down into different cognitive functions and examine their contributions to creative thinking? How might we experience its rewards more frequently? And is there any downside to creative thinking, any chance that it might in some circumstances lead to less rather than more flourishing?

The neuroscience in this area is very exciting. New brain-imaging tools are helping us to understand how creativity arises in our minds and how it is impacted negatively by factors such as stress, emotional dysregulation, sleep deprivation and interacting exclusively with people who think like us. Conversely, we can also observe the measurable positive effects on creativity of exposure to the arts, imaginative play, mindfulness, storytelling and even psychedelics.

If we're going to evolve alongside AI, thrive in an increasingly polarized world, tackle pressing challenges and experience greater well-being and more personal satisfaction, then it is imperative that we protect and develop our creative capacities. Rather than fretting about AI's ability to pull together a poem in the style of a teenage Shakespeare or its undoubted prowess in creative problem-solving, perhaps the smartest thing we can do is get curious about our phenomenal innate abilities, and explore our personal and collective creative powers. If we took simple concrete steps such as picking up a pencil and drawing pad to sketch what we see, or even just stared out of the window rather than at our phone, who knows what we might discover? Perhaps we would eventually experience our very own Eureka moment. That might be a catalyst for a discussion with someone else, which in turn could spark a cascading series of creative collaborations. Creativity is part of our evolved inheritance, a shared gift and a singular route to joy for every one of us. But what is it exactly, and how does it come about in the brain?

## What do we mean when we talk about creativity?



Our anecdotal understanding of creativity is often focused on its artistic outputs: painting a picture or writing a song. Or perhaps we think of more domesticated forms of creativity: baking a cake, making a meal or tending a garden. These are all examples of creativity, to be sure, but from a biologist's point of view, they're all still too specific. Biologists imagine creativity as a cluster of much more fundamental behaviours that collectively support problem-solving, such as seeking novelty, testing ideas through trial and error or combining new information with old. All animals can – and do – deploy creative ingenuity to solve a problem; their survival both as an individual and as a species depends on it. Human beings used to have a more direct relationship with their own creativity and that of other species, back when we made the objects we used every day, practised folk art and knew our fellow animals more intimately. With the advance of technology and industrialization, over time we forgot these things and became convinced that creativity was a higher calling, available only to our species and even then not to everyone but to a small subgroup of humans that we called artists, or innovators, or inventors.

Over the last few decades, scientists have played their part in reminding us of what Aesop knew when he composed his fables about animal ingenuity over 2,500 years ago. They've amassed incontrovertible evidence for animal consciousness, partly by pointing out the endless creativity of other-than-human animals. Small adult orangutans have been observed shaping leaves<sup>1</sup> to create whistles that they use to make them seem larger and more threatening to predators, for example. Octopuses pre-emptively hoard coconut shells<sup>2</sup> on the seabed, ready to don as portable shelter or armour when needed.

It turns out that even a yellow blob of slime mould can problem-solve. In 2010, a team of scientists at Hokkaido University in Japan<sup>3</sup> came up with a rather painterly experiment to test a hunch that our species' transport system could be improved thanks to the ubiquity of life's talent for creative problem-solving. They placed a piece of slime mould on a laboratory plate where oatmeal had been deposited in a formation mirroring the positions of the satellite towns that surround Tokyo. The mould instantly started to spread out in a network of veins to locate the oatmeal and then distribute the nutrients around itself. The pattern it created to join the bits of oatmeal

was strikingly similar to the incredibly intricate railway network of metropolitan Tokyo.

The scientists repeated the test using other global cities' transport systems<sup>4</sup> as their pattern, to check that the slime mould's mirroring wasn't a fluke. It wasn't. There *were* a few times when the mould took a detour. It didn't replicate the dreaded M4 motorway,<sup>5</sup> for instance, which links London to South Wales and has been voted by drivers as one of the worst roads in the UK, but settled on a different route, via the oatmeal equivalent of the Midlands. In general, though, the simple mould recreated tried-and-tested transport systems.

This amoeba-like organism has been evolving for a billion years. Given the countless generations of selection that have produced today's moulds, it's perhaps not surprising that they have developed a clever network strategy for foraging nutrients. What might give us pause is that researchers are turning to it to help redesign our transport systems, adopting its work as a 'template for urban design<sup>6</sup>'. Could this be a model for creative cross-species collaboration?

Designing a transport system or food-distribution network might not strike you as the pinnacle of human creativity, and it's possible that I'm guilty of anthropomorphizing the simple slime mould, but for me as a cellular biologist, this experiment is an invitation to every one of us to reclaim creativity for ourselves and consider how we can deploy it. Evidently the mould is not being imaginative or artistic but it definitely is engaged in creative problem-solving as applied to the crucial matter of survival, and in this it's typical of almost any species you care to mention. In opening our minds to such novel forms of collaboration, might we elevate our own creativity in the process?

When we talk anecdotally about creativity, though, we tend to think of it as something that is more than an ability to problem-solve, however innovative that may be. We think of it in terms of invention and originality, self-expression, agency and using our body in the service of our unique mind, whether through dancing or singing or wielding a paintbrush. Do other creatures have a self they wish to express? Does AI? These are the kinds of questions that can lead to philosophical brow-furrowing but also push us to think more flexibly, analytically and, yes, creatively, about how to make the most of our sophisticated human abilities.

In this chapter we'll be looking at how creativity arises in the brain via a range of different cognitive behaviours, from imagining hypothetical scenarios, mind-wandering and dreaming, to divergent thinking (coming up with novel combinations of concepts), play and playfulness, and improvisation – that is, innovating in real time by skilfully combining expertise and novelty-seeking intelligence. We'll also look at evidence to suggest that a key aspect of creativity is that it is a whole-brain activity. Since it involves numerous different regions, stimulating greater connectivity across our brain will support it. At every stage we'll be asking questions, in particular about how a cognitive behaviour can be either encouraged or undermined in everyday life. If creativity is innate in children, for example, how does it vary from one individual to another? Are people with ADHD especially creative? Are there any downsides to being a highly creative person?

Let's begin by delving into one of the key behavioural components of our creativity: our ability to imagine a scenario we haven't experienced in lived reality.

## Imagination: the basis of creativity

As human beings we have an incredible facility for leaping from one imagined scene to another, making our way through different hypothetical scenarios, recreating the past, dreaming of the future and conjuring up alternative realities. Does this imaginative ability underpin our creative intelligence?

Imagination is almost magical in its capacity to draw us into abstract realms, but it's also an everyday part of our lives, both yours and mine. You use your imagination every time you think ahead to plan a holiday or ask yourself what someone else might be thinking in a meeting. It's a crucial feature of your interior world. Imagine yourself walking through town to get to your favourite ice-cream shop or café, for example. Conjure up the scenario in your mind, close your eyes and picture yourself passing landmarks and navigating each street in sequence to reach your destination. Easy, right?

Everyday activities like that are a long way from the complexities of penning a novel, and yet both require you to untether your attention from your immediate surroundings and feel your way into a different cognitive

zone. Scientists believe that this ability to run through possible scenarios in our mind's eye probably evolved to help us to plan: from basic routes and projects to far more sophisticated undertakings, such as writing a book or a symphony or a doctoral thesis. We'll explore our capacity to think further and over lengthier timescales in [Chapter 3](#), but for now, you can see how, without imagination, carrying out complex tasks and reaching distant locations would have been impossible for our ancestors.

As with problem-solving, being able to imagine a hypothetical scenario is not exclusive to human beings. In 2024, a team of researchers in the United States<sup>7</sup> led by Albert Lee, Associate Professor at Harvard Medical School, conducted a series of neat virtual-reality and brain-machine interface (BMI) experiments to reveal how stationary rats can imagine themselves navigating virtual spaces with their thoughts alone. The BMI created a connection between the electrical activity in the brain of each rat and its location in a 360-degree virtual-reality arena. This allowed the researchers to trace how the rodents were preparing to navigate space in their brain. Firstly, the rats got to know a particular environment by physically exploring it and were rewarded with treats in certain spots. Then, without moving, they had to think their way, Jedi-style, into those spots associated with reward. They proved to be really good at it, able to successfully imagine their way to the virtual reward spots. This gave clear evidence that rats can anticipate events based on the past and modify their plans for the future: key skills that would help any species to learn, and hence to survive.

Those rats teleporting themselves through virtual-reality environments using a brain-machine interface may seem the stuff of science fiction, but we know exactly how they did it: in the same way that we do, through the activation of discrete circuits in the hippocampus. As we saw in [Chapter 1](#), this seahorse-shaped structure in the middle of the brain is involved in learning, memory and navigating space. It plays a crucial role in creating mental maps, including imagining potential future scenarios. In humans, the hippocampus also has links to the frontoparietal network (also called the central executive network and involved in goal-oriented, cognitively demanding tasks) and the default-mode network (involved in mind-wandering or daydreaming). As electrical oscillations dance across these regions in dynamic patterns of coupling and decoupling, they create an intricate neural architecture that supports us as we use our imagination.

The ability to imagine a scenario is the basis of so many other cognitive activities and sophisticated behaviours. Being able to visualize yourself doing an activity seems to pave the way for you to actually do it, for example. Sports coaches and music teachers have made use of this knowledge for years. Athletes are instructed to envisage the perfect jump or kick<sup>8</sup>; piano students are invited to imagine their fingers flowing over the keyboard<sup>9</sup> with total ease. Patients who are recovering their ability to walk after having a stroke<sup>10</sup> are shown how the power of their imagination will assist them in making a fuller recovery. But the role and value of our imagination goes beyond supporting us in physical activities. It also determines how we interact with others. Imagination is linked to empathy and emotional skills<sup>11</sup> and can help us to shift our mindset. If you can simply imagine helping others, for example, you are more likely to do it. Our imagination is one of the foundational elements in our ability to tackle tasks, be they creative, emotional or practical.

## Divergent thinking: fuel for creativity

Coming up with new ways to tackle old problems is essential to creativity; and many of us regard being original as almost a synonym for being creative. Individual originality attracts a premium in Western societies – just look at our centuries-long love affair with the figure of the lone genius – though it's not the only way to innovate. Neuroscience has recently provided evidence for the efficacy of a more collective approach to creativity, one that stresses drawing on many different viewpoints.<sup>12</sup> But whether you're trying to write a poem, for instance, or work with colleagues to craft a public-health message, you'll instinctively be reaching for novelty to succeed in your task. Cognitive scientists call this 'divergent thinking'. In plain terms, it's the ability to come up with new ideas that depart from accepted and conventional approaches.

The value of novelty is two-fold. Firstly, it might lead to a breakthrough solution for a tricky problem. Secondly, human beings are generally hard-wired to find it exciting, so both you and your audience or colleagues will be more engaged by a new concept than something that feels overly

familiar. That saliency creates a value of its own that complements the content of the novel idea.

Divergent thinking is a highly valuable component of creativity, but how does it come about and can it be encouraged? In 2018, a global group of researchers<sup>13</sup> set out to find answers to these questions by investigating how and where it arises in the human brain. What they discovered was that you can predict an individual's capacity for divergent thinking, and by extension a major strand of their creative powers, simply by analysing their resting-state brain activity as they lie in an fMRI machine. Even before the scientists asked their volunteers to do anything creative, they could – once they knew what they were looking for – predict which individuals would turn out to be good at it. This is significant because it suggests that there might be such a thing as a neural signature for original thinking, and if that is the case, we might be able to stimulate more of it among a greater number of people.

The scientists arrived at this potential breakthrough via a series of experiments that allowed them to test their emerging hypothesis and reverse engineer their way back to a robust conclusion. They first took 163 volunteers and asked them to perform a standard test for idea generation called the Alternative Uses Task (AUT). This is designed to measure the divergent-thinking strand of creativity and involves asking, for example: 'What could you do with a rolling pin aside from baking? How about a glass vase, besides putting flowers in it?' The test participants had to come up with creative uses for each everyday object that they could, within a set time. The more uses the better. Their answers were assessed for quality by independent assessors who were not part of the core team.

The team peered into the brains of the volunteers as they completed the test and identified patterns of electrical signals within a 'high creative network'. They saw dense functional brain connectivity, predominantly linking the default-mode, frontoparietal and salience networks. (The last is involved in communication, social behaviour and self-awareness. It integrates information across the other networks and acts as a switch between an internal way of thinking and a more externally focused and goal-directed style.) Collectively, these patterns functioned as signatures for divergent thinking. In contrast, they also identified a 'low creative network' in those individuals that performed less well, by spotting dense activity and



connectivity predominantly in the brain stem and subcortical structures, regions typically implicated in more habitual responses.

Associate Professor Roger Beaty at Penn State University was the lead author of this paper, and he identified the different roles played by these different brain regions: ‘According to this framework, the default network<sup>14</sup> contributes to the generation of ideas via flexible and spontaneous mechanisms involved in memory retrieval and mental simulation. The salience network, in turn, functions to identify candidate ideas – potentially useful information generated via the default network – and forward [them] to frontoparietal executive systems for high-order processing (e.g. idea evaluation, elaboration or revision).’ The scientists’ conclusion was that creativity – or at least its divergent-thinking component – is not confined to a single brain area. It emerges from the complex interplay between many regions and networks, including the hippocampus, frontoparietal, default-mode and salience networks. This so-called ‘high creative network’ supports the brain as it retrieves information, combines and recombines it, assesses new combinations for their relevance and revises them accordingly. These activities are connected and overlapping in time, and add up to that pleasing sense of your mind flexing and whirring in productive and creative ways.

To test their theory about high and low creative networks, the investigating team then took an entirely new set of study volunteers and asked them to complete similar but not identical divergent-thinking tasks. They wanted to be sure that their findings indicated general lateral problem-solving ability that could be applied in any situation rather than, say, a brain region that had evolved in one set of individuals to be especially handy at thinking up alternative uses for rolling pins and vases. The scientists’ quest for robust data was rewarded. The new round of tests revealed the same brain signature for the high creative network. Finally, and to really clinch the findings, they investigated ninety-three new volunteers, this time from Austria rather than America, and found the same correlations of high creativity associated with high activity in what they had identified as the creative brain network.

An exciting moment came when they found that, testing a new cohort of 405 adults, this time from the very culturally distinct country of China, they could accurately predict creative performance from an individual’s intrinsic functional brain connectivity. If there was higher connectivity across the

key brain regions the team had identified, even when the person was simply relaxing, that higher connectivity predicted their score on the AUT with considerable accuracy.

The team wanted to know whether they were truly measuring creativity or something more general about intelligence. It turned out that strengths in these creative networks in no way correlated with standard tests of crystallized intelligence (the accumulation of knowledge, facts and skills acquired throughout life that can be accurately measured using an IQ test). They had recruited their volunteers from America, Austria and China, to rule out culture playing a role, all with the same results.

It seemed that people with lower creative ability were relying on brain regions that support more procedural or habitual responses.<sup>15</sup> Their brain was drawing on previously learned thoughts without passing them on for further processing.<sup>16</sup> Highly creative people, on the other hand, didn't settle for an obvious albeit adequate solution. They kept going, in search of originality. None of this was a conscious choice, of course. It was simply the case that, in some people, there wasn't enough brain connectivity to allow their brain's capacity for creative flow to take over. Their processing remained at a certain level, without ever quite lifting off towards that Eureka moment.

The next question to ask is whether it's possible to strengthen our high creative network so that it takes over from the low creative network, and what can we do to encourage our brain to move in that direction?

## Mind-wandering: an incubator for creativity

One counter-intuitive answer might be to sit back and allow our mind to drift, out of focus. We are often told to live in the present and be mindful of the here and now. This is great advice for individual well-being, and mindfulness undoubtedly supports a whole range of healthy brain states including creativity, as we shall see. There's a different mental activity, however, that can be just as productive of well-being and nurturing of creative intelligence: mind-wandering. One of humanity's superpowers is precisely this phenomenal ability to untether ourselves from the here and now and mentally travel. Mind-wandering, which both draws on and feeds our imaginative powers and divergent thinking, continues to give us



significant advantages. While artificial intelligence can innovate, problem-solve and work creatively, it's harder to say how a large language model (LLM) – an AI system trained on a vast amount of text – could, for example, experience the sensation of a mind wandering freely, gently alert and open to any wisp of an idea floating by.

There is exciting research coming out to suggest that mind-wandering is how we get started on both using our imagination and divergent thinking. It happens spontaneously whenever our attention switches from a task to seemingly unrelated thoughts and feelings. That switching creates an opportunity for the default-mode network (DMN) to take over, and as we've just seen, the DMN is a key region in the high-creativity network, where it plays a role in initiating and incubating ideas, as well as in introspection and rest. Studies show that humans typically spend between 25 and a whopping 50 per cent of our waking hours on mind-wandering,<sup>17</sup> which suggests that it isn't a passive activity or a waste of time and energy. In fact, its value may lie precisely in its positive role in both creativity and well-being.

Allowing our mind to wander where it pleases is not the same as losing focus when we're interrupted by incoming signals. It's more like a process of internal free association than an interruption of flow, which does have a negative impact on our ability to sustain attention. Much has been written about the corrosive effect of being constantly distracted by the barrage of digital information we typically encounter in everyday life, but mind-wandering is different. It can be highly creative and relaxing, so it's worth understanding more about how it works rather than mistaking it for poor focus and jumping to shut it down.

Moshe Bor, a professor at Bar-Ilan University at Tel Aviv in Israel, and author of *Mindwandering: How Your Constant Mental Drift Can Improve Your Mood and Boost Your Creativity*, believes that mind-wandering allows for reflection in a gentle, unpressurized way. This in turn supports self-awareness and allows the brain to operate in a different mode from the high focus on the external world that is required in many cognitively demanding tasks. 'Creative thinking relies on a process<sup>18</sup> we call "incubation," where new ideas are generated and then evaluated,' he writes. 'Mindwandering, and the cortical network that mediates it, called the brain's default-mode network, is where such creative incubation takes place.'

There is more and more evidence stacking up in support of the idea of mind-wandering as an incubator for both positive states of mind and creative activity. A study published in 2019 in *Psychological Science* indicated that at least 20 per cent of our creative ideas occur during lengthier mind-wandering phases.<sup>19</sup> In an earlier study from 2018, mind-wandering was clearly associated with alpha waves,<sup>20</sup> which also correlate with meditative and positive states of mind. Alpha waves are the slowest of the brain's electrical oscillations when we are awake, with a frequency range of 9–14 cycles per second (measured in hertz, or Hz), where the full scale of brain-wave oscillations ranges from 0.1 to 100 Hz. Alpha waves predominate when we're relaxed and in nature, walking in woodland,<sup>21</sup> for instance, or bathing in a hot spring.<sup>22</sup> Dr Caroline Di Bernardi Luft and her team are based at Brunel, University of London. When they conducted the 2018 study, they discovered that it was possible to induce creativity by electrically stimulating alpha waves in the right temporal lobe (one of two brain areas on each side of the head, between the temple and the ear, typically associated with managing emotions, processing information from your senses, storing and retrieving memories and understanding language). The team asked volunteers to take tests for two different aspects of creative thinking and measured their brain waves as they completed them.

The first was the Remote Associates Test (RAT), devised in the 1950s, where volunteers try to find the link between three given words. It evaluates convergent thinking – a persistent and focused thinking state that identifies a correct solution to a well-defined problem. So, for example, in Square/Cardboard/Open the linking word is Box. In a harder example, Sense/Courtesy/Place, the linking or convergent word is Common, and, harder still, in Fence/Card/Master, the answer is Post. Convergent thinking depends on preliminary rounds of divergent thinking to identify numerous possible solutions. The additional cognitive skill of being able to quickly select the most appropriate solution from many is then added. It's applied divergent thinking, if you like. Caroline then added an extra layer of complexity to the task by listing groups of words such as Man/Cat/Sleep. Many people would quickly converge on 'nap' or 'rest' – but neither is correct. The answer is Walk (as in Walkman/Catwalk/Sleepwalk). To get there, participants needed to override that initial shared but misleading

association – and that’s where alpha stimulation in the right temporal lobe made the biggest difference.

Caroline noticed that getting a higher score on the RAT, where inhibiting obvious associations was required, was associated with the brain experiencing higher alpha-wave activity in the right temporal lobe. Wanting to test this relationship in a direct rather than observational way, she then applied alpha-wave stimulation to the volunteers’ right temporal lobe and found that she could increase their RAT scores by around 75 per cent.

Then she and her team moved on to the Alternative Uses Task for divergent thinking, the test we’ve encountered already in which participants are asked to come up with novel ideas, breaking down immediate and obvious associations and thinking outside the box. As we’ve seen, this is a necessary precursor in the convergent-thinking task, so if Caroline’s hypothesis was correct, she could expect to see higher alpha-wave activity in the right temporal lobe of the volunteers’ brains. That’s precisely what happened, and again, she found that she could manipulate scores, elevating divergent thinking by inducing alpha activity in this brain area through electrical stimulation. Her conclusion was that ‘right temporal alpha oscillations may be critical<sup>23</sup> to the inhibition of strong semantic associations’. In other words, alpha waves support creativity by acting as a neural mechanism to inhibit the obvious. This type of divergent thinking gets easier when we allow our mind to wander, and mind-wandering seems to be strongly associated with the brain’s slow and relaxed alpha waves.

In 2021, a team of researchers at the University of California in Berkeley<sup>24</sup> examined this hypothesis further by hooking up two dozen volunteers to an EEG machine. They confirmed what all the research was pointing to: there was elevated alpha-wave activity in the brains of volunteers when they were not focused on a task, and especially after completing an assignment that required concentration. It seems again that higher alpha-wave activity was an electrical signature for mind-wandering. Taking our minds on unconstrained and spontaneous thought journeys can spur innovative ideas and lateral problem-solving. It also promotes relaxation and well-being by serving as a restful respite from prolonged concentrated thought. Put simply, mind-wandering, daydreaming, whatever you want to call it, helps to create a flourishing, happy brain that’s buzzing with ideas and potential.

How can we ensure that we reap these benefits? We could try artificially inducing alpha-wave activity in our brain. There are helmets and bands for sale online that claim to electrically activate circuits at the required frequencies to enhance our mood and creativity. But the tried-and-tested methods for inducing mind-wandering are cheaper, less invasive and easier to access. Getting out into the natural world, going for a gentle stroll, doing the washing-up while listening to music or simply pausing and doing some stretches or just lying down and staring at the ceiling can all allow your brain to switch out of concentration mode and into mind-wandering. Making space in our increasingly busy and frantic lives for unfocused thought can help our mind to naturally gravitate towards one of its most healthy, creative states.

Conversely, an overstressed or hyper-focused brain is a less creative one. Stress is a good source of stimulation for our thinking in small amounts because it's a signal to focus, and when it's short-lived and forces us to concentrate on what is most important at the time, it has its place. The obvious danger is that if it becomes pervasive, signalling that everything is a priority that urgently requires our attention, it leads to cognitive overload and anxiety. And nothing is more guaranteed to shut down relaxed mind-wandering, open-minded enquiry and creative divergent thinking than worry<sup>25</sup>.

Focus plays an essential part in creativity since it's the mechanism by which divergent thinking's novelty-seeking expansiveness is whittled back down to considering the best options. When it complements the mind's imaginative and exploratory tendency, it can lead to the most exquisite outcomes. But without that initial round of roaming in search of the unlikely and unusual, focus will only ever deliver more of the same.

## Dreaming: a generator of creativity

Have you ever woken from a snooze with the exhilarating sense that you've just dreamed up the answer to a problem, or hit on a crucially interesting idea? If so, you're in fine company. Dreams have long been a source of inspiration for artists and scientists alike. Thomas Edison and Salvador Dalí, for example, recognized the importance of dreams to their innovative thinking. Both suspected that the early stages of sleep were particularly conducive to creativity, so they devised ways to wake themselves just as

they were drifting off. Edison famously napped while holding metal balls that would drop as he fell asleep, waking him in the process. He kept a notebook nearby to scribble down any ideas that arose during these semi-lucid moments.

There has always been plenty of anecdotal evidence to suggest that dreaming in the early stage of sleep is rich in imagery and ideas. Scientists, intrigued, have recently started to investigate further and discovered that this sleep stage, which they refer to as N1 (stage one of non-rapid eye movement (NREM) sleep) or hypnagogia, is characterized by high numbers of alpha waves in the brain. Given what we now understand about alpha waves in a waking brain, Edison's and Dalí's hunches about the almost sleeping brain seem well founded.

In 2021, researchers demonstrated that this twilight zone<sup>26</sup> between sleep and wakefulness does indeed ignite a creative spark that can be applied to problem-solving. The team, made up of scientists from Sorbonne University in Paris, Monash University in Melbourne and Paris's National Reference Centre for Narcolepsy, was led by cognitive neuroscientist Dr Delphine Oudiette. They gave 103 participants a series of mathematical problems to solve, which could either be performed step by step, or much more quickly if the participant realized that a cunning shortcut was possible. Participants who took a nap, Edison-style, while holding something heavy that dropped as they fell asleep (and spent at least fifteen seconds in N1 sleep) were three times as likely to discover the hidden shortcut as those who didn't sleep. The effect was striking – 83 versus 30 per cent. Interestingly, this boost to participants' intuitive problem-solving vanished if they reached deeper sleep. As Delphine concluded: 'Our findings suggest that there is a creative sweet spot within the sleep-onset period, and hitting it requires individuals to balance falling asleep easily against falling asleep too deeply.'<sup>27</sup>

In 2023, a team at the Massachusetts Institute of Technology (MIT) and Harvard Medical School<sup>28</sup> led by Dr Adam Horowitz expanded on this work by exploring a different aspect of creativity: storytelling. They conducted a clever series of studies using a device they'd previously invented called 'Dormio'<sup>29</sup> – a glove connected to an app that detects sleep states and incubates specific dreams. As the gloved volunteer enters N1 sleep, the app softly prompts them to dream about a specific thing: say, a

tree. When the wearer begins to enter the next stage of sleep, the app wakes them up, asks them to report what they were dreaming about and records their response. (Around 70 per cent of the volunteers reported dreaming of the suggested item – a tree in this instance.) ‘Dormio’ then prompts them to perform creative tasks, including listing uses for a tree, in this example, and writing a short story that includes the word ‘tree’.

Adam’s team found that a short nap and brief spell in N1 sleep before the tasks helped to increase volunteers’ creativity ratings in line with the results obtained by Delphine’s earlier study; participants who napped performed 78 per cent more creatively than those who stayed awake. But the really interesting bit was that those who had also received the targeted dream incubation performed 43 per cent more creatively than those who napped without it. They had a massive additional boost to their creativity beyond that which came from simply falling asleep. ‘It’s not just being in the N1 sleep state<sup>30</sup> that makes people more creative. People are more creative because they are harnessing the dreams that are occurring in that sleep state,’ says Dr Kathleen Esfahany, who was one of the researchers working on the study and is also based at MIT. ‘When you are prompted to dream about a topic during sleep onset, you have dream experiences that you can later use for creative tasks.’

Perhaps this boost to creativity is part of the reason we sleep; or rather, why we dream. There is an essential repair function to sleep, of course: it helps to clear out the toxins that have built up in the waking brain. It’s also crucial to learning, since it allows us to integrate what we have experienced during the day into our neural circuits, which in turn supports us to think in new ways when we wake up the following morning. But what is our consciousness doing while we sleep? Dreams must serve some purpose, and sleep research is discovering more all the time. Hypnagogia is turning out to be just as fascinating and possibly just as crucial to both creativity and well-being as its better-studied counterpart, REM (rapid eye movement) sleep, which makes up about 25 per cent of our sleeping time and is so called because the eyes rapidly move behind the eyelids. It is also a phase characterized by more intense and vivid dreaming. Like mind-wandering when we’re awake, it’s specifically the early-onset dreams that seem to help the brain to come up with novel ideas that lie just beyond our conscious awareness. What’s striking in Adam Horowitz’s study is how it shows that when prompted to dream about a particular topic, we can use this highly



creative sleep state to incubate innovative ideas about it and direct them, ready for us to draw upon when we wake.

Humans, of all the primates, spend a relatively small proportion of their life sleeping. We might get 7–8 hours a day whereas chimpanzees sleep for around 9.5 hours, cotton-top tamarins for about 13 and three-striped night monkeys are hardly ever awake, sleeping for 17 hours. Yet REM sleep occurs every ninety minutes and our ratio of REM sleep is relatively high.<sup>31</sup> Evolution whittled down humanity's sleeping time but protected REM sleep. Why? What's so important about dreams<sup>32</sup>, both those associated with REM sleep and the earlier N1 stage?

A study published in 2023 suggested a possible answer, viewing dreaming as a fundamentally creative and restorative act built around storytelling. David Samson, Professor of Evolutionary Anthropology at Toronto University, and his team examined how dreams vary across cultures<sup>33</sup>. He suggests that our ability to dream may have evolved as a strategy for cooperative survival, with the brain using dreams to craft narratives that help us process life experiences.

David compared dreams from forager communities in Africa to those from Western societies to analyse how cultural and environmental factors shape dreaming. He worked with the Bayaka tribe in the Democratic Republic of Congo and the Hadza in Tanzania to record their dreams over several months. These strictly egalitarian societies rely on cooperation and sharing of resources for their survival. David compared their dreams to detailed dream accounts collected between 2014 and 2022 from people living in Switzerland, Belgium and Canada. It turned out, unsurprisingly, that the two groups' dreams hinged around very different events, but what was striking was that the interpretations and moods that dreamers ascribed to their dreams were also very different. David described the dreams of the Bayaka and Hadza as being 'rich in community-oriented content<sup>34</sup>, reflecting the strong social bonds inherent in their societies. This was in stark contrast to the themes prevalent in dreams from western societies, where negative emotions and anxiety were more common.'

He cited examples of typical dreams in order to make his point. A Western participant reported: 'I [dreamt I] was with my boyfriend<sup>35</sup>, our relationship was perfect and I felt completely fulfilled. Then he decided to abandon me, which awoke in me a deep feeling of despair and anguish.' A

Hadza dreamer's recollection was very different: 'I dreamt I fell into a well. I was with two others and one of my friends helped me get out.'

David and his team found scarier dream narratives with less positive resolution in European and North American participants. The Hazda's dreams provoked significantly fewer negative emotions and often presented a resolution that incorporated a social solution. In David's words:

'Interestingly, while dreams from these forager communities<sup>36</sup> often began with threats reflecting the real dangers they face daily, they frequently concluded with resolutions involving social support. This pattern suggests that dreams might play a crucial role in emotional regulation, transforming threats into manageable situations and reducing anxiety.'

He speculated that fewer resolutions and higher anxiety in Western dreams might be linked to greater loneliness as more people live alone and with less community support. I find that highly plausible; but an additional conclusion for me is that our dreams allow us to rehearse possible solutions to future challenges through the medium of narrative. By imagining potential threats, we can test out consequences and uncover solutions in a safe space. When we're sleep-deprived, we're missing out on sleep's neurological housekeeping and the boost provided by dreaming for idea generation and incubation. No wonder tiredness has profound negative consequences for well-being and creativity alike.

## Storytelling: a tool for creativity

Dreams play into our species' reliance on storytelling. Human beings seem to be innately inclined to use narrative to shape our understanding and interpretation of the world. We've just seen how our dreaming brain deploys it to regulate emotion and make meaning; in [Chapter 4](#) we'll look at how our waking brain does the same thing when tackling uncertainty.

Storytelling also has a central role in the neurological mechanisms of perception, on both a collective and individual level. This begins with the brain's extraordinary capacity to build a representation of external reality, creating meaning out of chaos by imposing patterns on vast quantities of incoming data. We can consciously process only a minuscule proportion of the 11 million bits (a bit being the smallest unit of digital information) our brain is assaulted with<sup>37</sup> every waking second (perhaps 50 bits of this



total), so important messages inevitably get lost. To minimize this, the brain uses stories to help find signals within the noise, tagging them for relevance and amalgamating them into a narrative-like flow.

Groups have always used storytelling to create meaning via myth and culture. Storytelling's neurological basis in perception plays a part here too, adding up to a subconscious collective neural fingerprint. As we've seen, many studies have shown that when we take part in activities like singing together<sup>38</sup> or telling and listening to stories,<sup>39</sup> our brain waves synchronize with other people's so that we're perceiving events in harmony with one another. We literally begin to see the world in sync,<sup>40</sup> as our brains process those hundreds of incoming signals over the same timeframe. Whether it's our ancestors gathered around a campfire telling the story of a great battle or, in a modern context, friends meeting up to discuss a piece of gossip, when we share narratives we're co-creating the collective perception of the world that shapes the culture of a particular group. Listening collectively to stories and music programs us to think in harmony. Disagreement dials down, consensus is built; values and beliefs emerge, all through the mechanism of narrative, at both a conscious and unconscious level.

Rich visual detail made complex narratives easier to remember and share when culture was oral, before people wrote their stories down. It still makes them feel more compelling today. The human brain is highly dependent on visual signals to carry out its vital activity of perception. Our brains can process an image in 13 milliseconds<sup>41</sup> and compute a staggering 75 visual frames per second, which explains why up to 50 per cent of the brain's volume is dedicated to the gathering, sorting and evaluating of visual information. That's why stories that are full of visual prompts and set a vivid scene – whether we're reading or listening to them, or imagining or dreaming them – have greater impact. They're more salient, easier to comprehend and to remember. This heavy reliance on visual imagery might also answer the question of why humans have so many vivid dreams compared with other primates, courtesy of all that REM sleep.

According to David Eagleman, a neuroscientist, author and science communicator based at Stanford University, California, highly visual dreaming evolved to ensure that the visual cortex is protected and reserved for this function even when our eyes are closed for lengthy periods of time. Research into brain plasticity has demonstrated that if activity slows or

stops in any region, its territory tends to be taken over by its neighbours.<sup>42</sup> This happens surprisingly quickly, in less than an hour. The brain's ability to adapt quickly to changing environmental inputs makes it flexible in the face of challenge. Mammalian brains have all evolved this capacity to be adaptive because it's such a useful mechanism, but the human brain is particularly adaptable. When Eagleman analysed twenty-five species of primates, he found that plasticity in the visual cortex correlates with the proportion of REM sleep. He suggests that our REM sleep has been protected throughout evolution in order to ringfence our species' crucial visual system by charging it with activity periodically throughout the long dark nights. In this way, it defends its territory against takeover from other senses in our highly flexible brains. We imagine we 'see things' in our dream, and this protects our visual cortex by keeping it active and exercised while we sleep.

There is a cautionary tale here for me. Our brains are unusually plastic, which has allowed our species to learn, adapt and create in exceptional ways. It's a great strength but also a potential weakness. When I first started my PhD research on brain plasticity<sup>43</sup> around twenty years ago, the phrase 'use it or lose it'<sup>44</sup> was starting to be commonly used, applied to cognitive skills like memory and agility of thought. For me now, it highlights the value we should place on our innate creativity, our ability to mind-wander, to dream, to imagine and seek original thoughts. If we don't nurture and practise these skills, there's every chance they will atrophy as the brain regions that support them are encroached upon.

Storytelling is a key strand of human creativity and one we can all access at many different levels. You don't have to write a novel (unless you really want to, of course!), but reading one and telling your friend about it, in person, is a great way to nurture your creativity and empathy. Keep a notebook by your bed and write your dreams down every morning; or paint them, like Dalí did. Draw comics, tell jokes, follow your narrative inclinations wherever they take you. When I'm out hiking with my son and our friends, we often create stories together a line at a time. We take turns to add a sentence to the narrative and see where we collectively end up. It's great fun on walks, camping trips and long car journeys, and exercises storytelling skills and emotional intelligence as we all work together to create something new.

# Hyperphantasia: the benefits and risks of an exceptionally vivid imagination

Telling stories is one of the key ways human beings flex their imaginations, and as we've seen, a story rich in visual imagery is more compelling to tell and to listen to. But some of us are more visually imaginative than others. Do you find it easy to visualize situations in strong mental images, or do you struggle to conjure up a clear picture in your mind's eye? There is far more variation on this matter than you might realize, and it's an area that scientists are increasingly investigating. You may never have thought about whether you do or don't have a range of vivid mental imagery at your disposal, so I'd like you to pause for a moment and picture the following scenario: 'The sun rising above the horizon into a hazy sky.'

What level of detail did your mind conjure up, on a scale from 1 to 5, where 1 is no image at all and you only 'know' that you are thinking of the object, 2 is vague and dim, 3 is moderately clear and bright, 4 is clear and reasonably vivid and 5 seems perfectly clear and as vivid as real seeing?

It's tricky to do this test on yourself of course, and one person's moderately clear might be another one's vague and dim, but when used in a clinical setting with a large number of test participants, the Vividness of Visual Imagery Questionnaire (VVIQ)<sup>45</sup> is both accurate and revealing. Participants are asked to visualize sixteen different scenarios and report the level of detail they see using the five-point scale. The final score is the sum of all sixteen responses, with a maximum of 80 points. In large surveys, most people score around 55 to 60. Around 1 per cent score just 16<sup>46</sup> and are considered to have extreme aphantasia, meaning that they lack virtually all visual imagination; 3 per cent, meanwhile, achieve a perfect score of 80, which is extreme hyperphantasia – a condition characterized by having an exceptionally vivid visual imagination.

Geraldine van Heemstra is one of those 3 per cent, an artist and printmaker whose work is inspired by nature and the elements (see the images on [page 65](#)). She took me on a tour of her studio and showed me some of her creations, including devices she built to record the wind, and pieces she made using found objects washed up on a beach. She'd recently returned from Newfoundland, where she'd been filming and finding inspiration for her next art show. 'I love working outdoors<sup>47</sup> but when I'm

back in the studio, I try to relive that moment,’ she told me. ‘And with my imagination ... I can get right back there.’

When I asked Geraldine whether she had been aware of this ability from a young age, she told me she had always assumed that ‘everyone thought like that. I would make an imaginary town from imaginary building blocks, with a cathedral and a town hall, all laid out in the living room, and then get upset when my brother walked through the space, knocking over buildings and sending bridges crashing into rivers. As far as he was concerned there was nothing there, but in my mind it was all so real.’

Her imagination would take over in the classroom just as it did when she was playing at home, and the results could feel distressing and distracting. ‘I always had colours in my mind,’ she said. ‘When I did maths, all the numbers had colours.’ Geraldine has not been diagnosed with synaesthesia – a phenomenon that causes sensory crossovers, such as tasting colours or feeling sounds – but suspects she does have it. ‘I was a real dreamer,’ she continued, ‘and I would play around with the numbers. I knew the correct [mathematical] answer, but I didn’t think [the colour] looked so nice, so I would change the answer to a colour I preferred. Naturally my teachers either thought I didn’t know what I was doing or that I was just mucking about. I didn’t know how to explain to them what was going on. I still don’t like maths.’

Geraldine’s condition was identified thousands of years ago by Aristotle, who described it as a sixth sense of visual imagination called ‘phantasia’, but it has only recently been studied by neuroscientists. We know, for example, that hyperphantasia (as it is now called) is associated with ‘creative’ professions. It’s far more common among children<sup>48</sup> but fades across adolescence and into adulthood, with only a small percentage of people who’ve managed to retain it in later life. When we analyse the brains of these individuals<sup>49</sup> using fMRI scans, we find they have greater connectivity between the prefrontal cortex, which is involved in ‘higher-order’ thinking such as planning and decision-making, and the areas responsible for visual processing, which lie towards the back of the skull. This helps to explain why if you say ‘beach’ to them, their brain will immediately transmit the word to the visual system, so that they see it.

Hyperphantasia can also extend beyond highly visual imagery to create a sense of being vividly immersed in a different world. Geraldine explained that when she is reliving a memory or reading a book, all her senses are

engaged so that she feels utterly transported. ‘I can see the whole story in front of me. The colours, the taste, the smell.’

Clare Dudeney, who also has hyperphantasia, spoke about her experience for a piece published in the *New Scientist*. She emphasized its darker side.

‘When people describe things<sup>50</sup>, especially gory things, I visualise them so vividly it’s like I’m experiencing them first-hand,’ she said. ‘A few years ago, I was on the train reading a passage about someone who got a nail stuck in their foot and I passed out.’

When I ask Geraldine about this aspect of her condition, she agrees, explaining that she is careful about which worlds she gets immersed in. ‘I often find TV series too intense. I plan my watching for evenings when I don’t have anything important the following day because I know that I will go to bed with that image or story going through my mind like the camera is still rolling. It can be overwhelming, especially if the material is designed to be scary. Nowadays nothing’s left to the imagination!’

This link between hyperphantasia and mental distress offers a tantalizing sliver of insight into the long-standing anecdotal coupling of exceptional creativity with mental health, or lack of it. The tortured genius is a cliché with staying power. Even if we confine ourselves to Western visual artists of the last 150 years, it doesn’t take long to come up with a lengthy list of sufferers, including the painters Vincent van Gogh, who was admitted to a psychiatric hospital for what seems to have been severe bipolar disorder, and Mark Rothko, who was a depressed alcoholic. Such famous figures may stick in our imagination, but it’s always been tricky to point to any real evidence of correlation, let alone causation. And yet there has been a lingering cultural anxiety that speaks to our fear that prioritizing creativity in our own lives might somehow make us less resilient to life’s stressors. Does hyperphantasia provide the answer to the question of why some extremely creative people struggle to interact with reality?





Two works by Geraldine van Heemstra, who has been diagnosed with hyperphantasia – a condition that affects 3 per cent of the population and is characterized by exceptionally vivid visual imagination. Top: *Shifting Realities III* (2021) monotype with watercolour and peat on Japanese kozo paper, 49 × 99cm). Bottom: *Breaking into a Thousand Lights* (2023) mixed media on linen, 80 × 160cm).

In 2018, Adam Zeman, then Professor of Neurology at Exeter University, and his team conducted an experiment<sup>[51](#)</sup> on the brain activity of people like Geraldine and Clare, as their brains rested and as they looked at particular scenes and then closed their eyes to imagine them. He found that people who rated their mental imagery very highly on the VVIQ had stronger connections between ‘thinking regions’ at the front of the brain and visual

regions towards the back. As he explained to me: ‘Thought seems to translate automatically into image<sup>52</sup> in such folk.’

I spoke to Dr Reshanne Reeder, a lecturer at Liverpool University who also studies extreme mental-imagery conditions such as Geraldine’s. She explained that this negative aspect is typical. ‘[Such] people struggle to control imagery<sup>53</sup> and other sensory inputs. If they hear something disgusting at the dinner table, for example, they might lose their appetite for the whole night. Or if they think about something scary while walking home in the dark, they really freak out. I suspect they’re more prone to maladaptive daydreaming, which is when your mind-wandering is so vivid that you can’t pay attention to something else, such as the road when you’re driving. Similarly, people with hyperphantasia seem to be particularly prone to nightmares and night terrors – very vivid images that are almost like hallucinations. Awake or asleep, the imagery is so vivid that it can contribute to enhanced negative emotions.’

Geraldine has learned to protect her mental well-being from her imagination’s dark side. It takes conscious effort but she has figured out how to resist negative spirals. ‘I know what uplifts me. I can close my eyes and imagine myself walking on the beach with my feet on the sand. If I’m struggling to motivate myself to finish a task, I imagine making myself a treat of hot chocolate with cardamom once I’m done. I can pretty much smell the scent of melting chocolate. Or if I’m feeling worried about an upcoming event, then I consciously visualize myself succeeding.’

Geraldine uses her imaginative power to soothe herself in the present and set goals for the future. She can safely explore different scenarios and identify a path that will help her achieve her objectives. She told me about feeling energized by this focused imagining, as if she were more able to tap into her intuition and spot opportunity. ‘I develop a sense of clarity about where and what I’m aiming for. It’s as if my senses open [up] to things that relate to that path. It might be a conversation with someone that I wouldn’t otherwise have had. I love it when serendipity happens!’ We’ll return to the power of intuition and its physiological basis in interoception, the nervous system’s internal sixth sense, in [Chapter 4](#) on coping with uncertainty.

Reshanne has heard from people who initially score moderately on the VVIQ who have trained themselves to elevate their imaginative powers. She thinks we all could boost our imagination and learn to focus it in a positive direction by undertaking daily exercises, particularly if we do this

during a critical period of neurodevelopment – adolescence – which is when the hyperphantasia frequently experienced by children<sup>54</sup> starts to diminish. Reshanne told me she suspects ‘that a lot of people lose natural hyperphantasia during neural pruning’ (the natural loss of nerve cell connections that occurs throughout life<sup>55</sup> but particularly during adolescence) ‘and that it would be very difficult (if not impossible) to “train it back” once lost. However, if people consistently exercise their imagination with creative activities such as visual art or story-writing, they can maintain and possibly increase the vividness of their imagery into and throughout adulthood.’ You could try a guided meditation, she suggests, or listen to an audiobook and really conjure up the scenes in your mind’s eye. It could be as simple as imagining yourself walking through your favourite holiday location. It doesn’t matter so much what you’re imagining, only that it’s something positive and familiar enough for it to feel relatively effortless so that you put in the practice. Reshanne also recommends keeping a journal next to your bed and making a note of any dreams in as much detail as possible. ‘Gradually you’ll get better at remembering them and they will feel more vivid in your recollection and more available to your conscious mind. With practice you’ll be able to tap into lucid dreaming states, with all their possibility for originality.’

People with hyperphantasia seem to spend more time daydreaming than most of us, presumably because they have such rewardingly vivid material to work with. As we will also see in improvising musicians, they hit a level of expertise and comfort that allows their creativity to become effortlessly pleasurable. A far cry from the tortured genius of the popular imagination. We could all try to emulate them and reap the rewards for both creativity and positive states of mind.

## Highly creative brains: ADHD

I began my PhD twenty years ago at the height of the genetics-driven revolution in research, and looked at how the circuitry for our unique brain was determined by the genes we inherited from our parents. There has since been an explosion of research examining the role played by our environment. Genes are of course fundamental, but epigenetics (the study of how our environment influences our genes by altering the chemicals



attached to them) tells us how gene expression can change from one generation to the next. Increasingly we're asking whether human beings have created such a radically engineered environment, through digital communication and artificial intelligence, that our culture has become so powerful that it's reshaping our individual brains within our lifetime. It's this mind-blowing acceleration of timescales that provided the initial stimulus for me to think about the very concept of a brain that's fit for the twenty-first century.

But in the meantime, of course, genes and their influence haven't gone away. Genetics remains a crucial scientific frontier that dovetails with neuroscience's enhanced brain-imaging techniques to deepen our understanding of how the brain develops from its foundations, pre-birth. There are no doubt hundreds if not thousands of genes that converge to play a part in the incredibly sophisticated and complex trait of creativity; that said, there is one clear common theme. Genes involved in dopaminergic transmission come up time and time again.

Dopamine has been dubbed the brain's pleasure chemical and is heavily involved in the motivation and reward pathways. It makes sense that dopamine-related genes have been identified as candidates for involvement in creativity, given that so many of the brain's key cognitive behaviours, from novelty-seeking to flow states, depend on motivation and reward, which in turn are underpinned by dopaminergic neurotransmission. On the level of lived experience we probably all know that creativity feels pleasurable. If you happen to carry a high number of genes involved in dopamine transmission, might you be predisposed to higher creativity?

Taking this suggestion one step further, what might we learn about creativity from people with ADHD, a condition also associated with altered dopaminergic neurotransmission and a preference for making new associations rather than relying on previous ones? To explore these questions, I decided to speak to a friend who was diagnosed with ADHD five years ago when she was thirty-eight. Amy isn't a scientist or a doctor. She's had a varied career that's taken her from journalism to creative strategy and now on to photography. By the time of her diagnosis, Amy's ADHD had impacted her life in different but typical ways. Her school reports always said things like 'Amy is very smart but she's not living up to her potential' or 'Amy easily gets distracted' or 'She distracts the class'. When Amy was diagnosed with the condition, she felt 'a huge amount of

grief”<sup>56</sup>. She began to realize that coping with ADHD had placed a strain on multiple aspects of her life.

Scientists have demonstrated that attention-deficit/hyperactivity disorder (ADHD), classically characterized by distractibility, impulsivity and hyperactivity, is often linked to a poor record of academic achievement and employment and in relationships. We also know that it is a condition with very high heritability, around 80 per cent,<sup>57</sup> in which we see altered activity in the ‘brain reward cascade’, especially in the dopamine system.<sup>58</sup>

This can play out in many ways. Amy finds it difficult even to leave the house on time, because the chain of simple tasks it requires, from getting dressed to packing her bag, is hard to focus on. Other activities become more compelling, she loses track of time and has difficulty concentrating on what she’s meant to be doing. Amy sounds upset with herself as she explains this to me, fully aware of the impact she is having on other people and the way it’s perceived. When she does latch on to something, particularly a project in its early problem-solving, brainstorming phase, her dopaminergic reward response swings the other way to operate at full throttle. Amy is capable of extreme focus, deep concentration on the task in hand and long-term tenacity. Once she’s in that mode, she tends to get so immersed that she again completely loses track of anything and anybody else. ‘I go into this zone where I do things so much deeper and faster than other people,’ she explained to me. ‘But if you were to come and interrupt me when I’m in hyperfocus mode, it literally breaks me. I get so irritable.’

She gave me an example of how this can play out. ‘I was working on a presentation for a really important project at work and I realized I was going to be late home to do dinner for my son. So I called my partner to apologize and explain that I was leaving in five minutes and would be about twenty minutes late. The next thing I knew was that he was calling me, very sweetly, saying, “I’m just wondering when you’re coming home.” I was really frustrated because I was on the cusp of cracking the presentation and I’d just told him that I would be leaving in five minutes. He said, “Amy, two hours have passed since we spoke and River’s kind of waiting for dinner.” I was horrified. I had no idea. So I started to finish up, but because I was still in hyperfocus mode, I fell straight back into the task. I was just going to write a couple of sentences to wrap it up when I got another phone

call, and learned that another hour and a half had passed. I hadn't noticed a thing. Hadn't even glanced at the clock.'

It is not uncommon for people with ADHD to lose track of time and the world around them when they're in a state of hyperfocus. This might be linked to changes in the frontal lobe that controls our sense of reward, meaning that certain tasks become so all-encompassing it's hard to disengage. If you're an improvising jazz musician, this flow state is considered a benefit, but for people with ADHD, who struggle to achieve focus in the first place and then to redirect their attention when necessary, it can be seriously problematic. It is often perceived as disregard for other people's time and priorities, and requires a lot of patience and understanding that may or may not be forthcoming.

Amy is infectiously imaginative, energetic and enthusiastic, with a very clear zest for life and a brain constantly brimming with creative concepts. High creativity is typical of people with ADHD, who generally display enhanced lateral problem-solving and divergent thinking. They show greater imaginative thought and an ability to expand on new concepts with ease. They can come up with lots of innovative ideas and enjoy running with them, which is what Amy often ends up doing when she's meant to be leaving the office to head home.

In 2022, Martine Hoogman, Assistant Professor at Radboud University Medical Centre in the Netherlands, published a study that investigated the link between creativity and ADHD.<sup>59</sup> The first phase of the research involved a group of 470 adults without any diagnoses. It assessed them for having ADHD-like symptoms and then analysed their performance on a range of tasks to gauge fluency, flexibility and originality. Those with more ADHD-like cognitive behaviours did better, with higher scores on the Alternative Uses Task for divergent thinking. They did not, however, score higher on the Remote Associates Test for convergent thinking, which requires a greater level of inhibitory control from the frontal cortex to stay on track so that you can narrow down options and settle on an unobvious answer. In the second phase of the experiment, this time using data from 151 adults who had been diagnosed with ADHD and from control groups, Hoogman's team discovered that those with a formal diagnosis of ADHD also performed at a higher level for divergent, but not convergent, thinking.

This research supplies one possible explanation for what's going on during the processes – sometimes frustrating, other times exhilarating – that

Amy described to me. People whose brains are inclined to ADHD-like behaviours are likely to be excitably firing off new ideas all the time. They can stay motivated and hyper-focused in an initial brainstorming phase, and their brains can very successfully dampen down inhibition to allow multiple creative thoughts to be expressed. But they might struggle with the finer detail or the more precise development of ideas, and find it hard to follow through to completion.

As author Matthew Syed points out in his bestselling book *Rebel Ideas*, groups of people who all think in the same way often end up with the same or similar ideas – leading to mental stagnation and a lack of innovation. In this context, perhaps we should be valuing the innovative flair of individuals with ADHD rather than labelling their lack of focus and their hyperfocus as a disorder. After all, as Syed writes: ‘Cognitive diversity was not so important<sup>60</sup> a few hundred years ago, because the problems we faced tended to be linear, or simple, or separable, or all three ... a physicist who [could] accurately predict the position of the moon [didn’t] need a different opinion to help her do her job. She [was] already bang on the money. Any other opinion [was] false ... Thinking differently [was] a distraction. With complex problems, however, this logic flips. Groups that contain diverse views have a huge, often decisive, advantage.’ Having a person with ADHD on your team could boost overall creativity by disrupting the default approach and widening the conceptual space to allow new ideas to spring forth. Maybe those with ADHD are the creative catalysts that we so desperately need to cope with existential challenges, fast-paced technological change and accelerating behavioural trends in global societies. Is ADHD a trait to be cherished rather than given a negative label and quashed?

In 2008, Professor Barbara Sahakian and colleagues<sup>61</sup> at Cambridge University published a paper titled ‘The innovative brain’ in the journal *Nature*, which fits with this theme. ‘What works for successful entrepreneurs,’<sup>62</sup> she explained to me when we spoke, ‘may also work for some creative people with ADHD.’ In the article she proposes that entrepreneurs’ activities are ‘an example of highly adaptive risk-taking behaviour<sup>63</sup>, with positive outcomes in the context of stressful economic decision-making’. This ‘functional impulsivity’, as she calls it, ‘may have evolutionary value as a means of seizing opportunities in a rapidly changing

environment'. Functional impulsivity and all the other creative and adaptive skills that entrepreneurs and people with ADHD-type brain profiles exhibit are only going to become more valuable in the twenty-first century.

Amy is now a coach who helps other women with ADHD from her base in Cambridge. While she welcomes the recognition that ADHD is not merely a disorder or a problem, she doesn't want to downplay how challenging it can be to make the most of its positives while coping with the negatives. She spent decades masking her symptoms and forcefully dampening down her curiosity and hyperfocus to try to achieve in the classroom or office. These days she celebrates the superpowers the condition has brought with it and helps others to identify their own. One of the first things she does in her workshops is encourage women to break out of this dampening of their natural artistic flair. '[Those with] ADHD are incredibly curious,' she told me. 'They never stop asking questions. I encourage them to play, because play is linked to curiosity and curiosity shuts off fear.' She also advocates questioning rather than accepting the status quo, being open to other possibilities and imagining different scenarios as participants allow their minds to wander freely, without fear of being ridiculed or worrying where those thoughts might take them. She readily agrees when I suggest that, given everything scientists are uncovering about the functioning of creativity, this is good advice for all of us.

## Playful creativity – and how to retain it

I suspect that many people are blocked from their creativity more by lack of confidence than lack of expertise. Even if we put the hours in to become a skilful practitioner, we might struggle to let go of inhibition and follow our creativity towards innovation. Why do we cut ourselves off from this joyful feeling? When did we forget how to play? Perhaps you have your own answer. Maybe you were shamed by a long-ago criticism from an art teacher at school or told by your career advisers that creative pursuits were not serious or credible activities for an adult.

And yet, human beings are, by and large, straightforwardly creative as children. Whether we analyse children's creativity in a laboratory or simply observe toddlers in a nursery group, there is no escaping the conclusion that creativity starts early. Children are naturally exploratory in the way they

interact with the world and they display playful, uninhibited thinking. They're constantly testing out unusual combinations of food, dreaming up a best friend who is a dragon, or looking for different ways to wear their socks. This playful exploration in the absence of received knowledge about why you can't eat jam and Marmite together, or put your socks on your hands and ears, is all part of a child's learning process. It's how we begin to make sense of our complex environment. Even babies are taking their first steps in creative exploration when they grab for an object or put something in their mouth to discover how it feels. We are all (to differing degrees, admittedly) born naturally curious and creative.

Assistant Professor Barbara Pomiechowska from Birmingham University in the UK believes that 'human creativity has no boundaries' and that it is absolutely innate, but she wanted to know more about how and when it emerges in a baby's brain. She therefore designed a study with colleagues at the University of Birmingham and Central European University in Austria and Hungary to investigate. She decided to do this by looking at one very specific, and testable, behaviour<sup>65</sup> that humans typically start to develop from a very young age – language acquisition. She took sixty babies, all around twelve months in age, all monolingual and growing up in Hungarian-speaking families, and taught them two new, non-Hungarian words for quantity: *mize* (to mean 'one') and *padu* (for 'two'). The babies were then asked to combine these two words with different objects – for example, to identify '*padu* ducks' from among a selection of images. The idea was that by teaching novel words to represent quantities, the scientists could test the babies' ability to combine new concepts in real time rather than simply recall combinations of words that they already knew from previous experience. The scientists used eye-tracking technology to monitor where the babies were looking, and found that they successfully combined the two concepts to understand what they were being asked about.

The ability to quickly learn new things and apply them instantly in different ways (one of the bedrocks of creativity, as we've seen) does indeed seem to be innate in young infants, but does it get lost as we age? Is a toddler more creative than an eight-year-old, and is the eight-year-old more creative than a sixteen-year-old?

This was precisely the question that George Land and Beth Jarman set out to answer in what became a seminal study of creativity that they conducted in 1968.<sup>66</sup> Having previously designed a test for NASA to select

the most innovative engineers and scientists, they decided to use an only slightly modified version to test 1,600 children between the ages of three and five for their creative abilities. The same children were tested again at the age of ten and again at fifteen. They found that an astonishing 98 per cent of those kids displayed what would have been genius-level creativity for an adult engineer at the initial test. But as they grew older, their skills diminished: only 30 per cent were still high scorers at ten years old and 12 per cent at fifteen. The same test was given to 280,000 adults (with an average age of thirty-one): they scored a rather pathetic 2 per cent on the creativity scale. George and Beth proclaimed that society's constraints were snuffing out humanity's inherent creative genius.

That may be at least partially true (I suspect it is), but there's also a core biological mechanism that underlies the truism. During the typical human lifespan, brain changes occur that will naturally diminish our creative ability. There is a trade-off between expertise and creativity, as we will see when we think about improvisation. The same thing happens with everyday perception. As we enter adulthood our brain takes more shortcuts in information-processing, basing its assessments on prior experience rather than the unique reality of the moment. That translates into the many habitual thoughts and behaviours that gradually accrue to make up our identity.

This is a feature of our brain's processing, not a bug: there's a huge imperative to rely increasingly on prior knowledge because perception is so metabolically demanding. Our brain requires around 20 per cent of our daily intake of calories simply to sustain the physiological mechanism that enable us to process information from the world around us, create our reality and instruct us how to interact with it. Humans evolved to take shortcuts in information-processing to conserve energy. We can't do that from birth because we need to build a bank of stored information in the first place; but the older we are, the more layers of processing filters our brain has acquired. Some of those facilitate fast processing but some of them result in bias and blind spots. As we age, we naturally stop seeing possibilities and start seeing constraints. And that's without factoring in any damage or accumulated wear and tear to our neural circuits.

What can we do to resist the ossification of our creativity? For a start, we might want to rethink the way we push children to stop playing and start cramming for tests from an increasingly young age. There has been a great



deal of research into the impact of a regimented curriculum and frequent testing for primary-school-age children in countries like the UK, versus a later start in school and more emphasis on play in places like Finland. As psychologists Emily and Laurence Alison write in their book *Rapport: The Four Ways to Read People*: ‘Recent studies have suggested that non-stop exam prep<sup>67</sup> and a dearth of unstructured daytime play is having a negative impact on children’s emotional and cognitive development.’ They hold the view, which I share, that when our schools focus too much on preparing children for standard tests, they are teaching a narrow range of skills at the expense of the very cognitive behaviours that stimulate and support creative problem-solving. In line with this view, the country that tops the World Economic Forum’s Global Report for Education is Finland.<sup>68</sup> And, you’ve guessed it, the Finnish delay formal learning until age seven, incorporate play within the structure of the school day and prioritize learning through play throughout the curriculum.

Once we’re adults, we need to make the effort to embrace playfulness. If you find this concept difficult and feel rusty about playing, one way to start is to identify your play personality. Are you the Collector, who enjoys building collections such as stamps or model vintage cars? Are you the Competitor? You might enjoy participating in (and winning) games with specific rules, playing for a neighbourhood football team, for instance, or competing in a games night at your local café or pub. Are you the Creator or Artist? If so, you find joy in making things, or making things work. You might enjoy drawing, woodworking, decorating, fixing machinery or sewing. Perhaps you’re the Director, in which case you enjoy planning and directing activities, such as hosting themed birthday parties. If you’re the Explorer you play by discovering something new, either physically (a new place on holiday) or mentally (a new musical artist or genre). The Joker likes being silly and entertaining others. You might enjoy improv theatre or simply making your friends laugh. The Kinesthete enjoys playing by moving their body. You might practise yoga, for instance, or take a dance class for fun. The Storyteller plays by listening to or creating stories. You might enjoy going to the theatre or writing a journal. And of course, you’re not restricted to one personality. Perhaps a number of these different play styles appeal to you. In which case, give yourself permission to explore them all. It’s good for you!

As I age ungracefully, I treasure the evidence that being playful helps me to retain my creativity. Dr Stuart Brown, founder of the National Institute for Play and co-author of *Play: How It Shapes the Brain, Opens the Imagination, and Invigorates the Soul*, makes the case that play is anything but trivial. He likens it to flow, describing it as that ‘state of mind one has when absorbed<sup>69</sup> in an activity that provides enjoyment and a suspension of sense of time’. He makes the case that play is a biological drive as integral to our health as sleep or nutrition, while his book describes how ‘we are designed by nature to flourish through play’.

## Can use of psychedelics create a playful mindset?

Artists have long played with mind-altering substances to open the doors of perception and explore divergent thinking. Anecdotally, classic psychedelics such as LSD, psilocybin or ayahuasca may enhance creative thinking, but the results of scientific studies on this are mixed at best and certainly nuanced. Over the last decade or so there has been a renaissance in academic research into the use of psychedelics to treat psychiatric illness, which has delivered many promising results, but the study of their use to boost creativity is very much in its infancy. A recent review of the literature indicates that psychedelics might temporarily increase the flexibility in the brain<sup>70</sup> required to generate novel ideas, but possibly at the cost of the sustained attention that is required for the evaluation and deployment of those ideas. In essence, psychedelics increase divergent thinking at the expense of convergent thinking, making users all a little more like people with ADHD, or restoring them temporarily to a childlike mindset. They entail the same trade-off: more originality and a higher quantity of innovative ideas but less capacity to apply them in a sustained way. This effect was found in different settings and with various psychedelics, including at ayahuasca retreat centres,<sup>71</sup> with LSD administered in the laboratory<sup>72</sup> and with smaller doses of lab-administered psilocybin.<sup>73</sup>

Psychedelics cause profound and widespread changes to the brain’s functional networks. They seem (possibly counter-intuitively given what we’ve seen elsewhere about connectivity being crucial) to disrupt

connectivity within parts of the default-mode network. In a recent study conducted by Dr Joshua Siegel and colleagues<sup>74</sup> at Washington University School of Medicine in St Louis, they observed huge swathes of changes in parts of the DMN during psilocybin use, and then, when the acute effects of the drug had worn off, how small connectivity differences, particularly between the DMN and hippocampus, persisted for weeks. In contrast, participants in the study who were acting as controls and given the ADHD drug methylphenidate showed a relatively stable connectome throughout. Joshua explained the theory behind what was going on: ‘The idea is that you’re taking this system<sup>75</sup> that’s fundamental to the brain’s ability to think about the self in relation to the world, and you’re totally desynchronizing it temporarily ... In the short term, this creates a psychedelic experience. The longer-term consequence is that it makes the brain more flexible and potentially more able to come into a healthier state.’ It’s thought that over time these changes in connectivity in the DMN result in ‘a psychedelic mind’ – one that is more flexible and less constrained, self-referential or bound by ego.

But can these findings translate to the real world? Few of us are willing or able to take the sort of doses that are administered under controlled conditions in a laboratory, not least because LSD, psilocybin and other psychedelics are controlled substances and illegal to sell or buy. Besides, the evidence for the efficacy of microdosing (taking small amounts that don’t result in ‘a trip’, typically as part of a weekly routine), which has gained huge popularity in recent years, is very patchy.

Neuropharmacologist Dr Suresh Muthukumaraswamy of Auckland University<sup>76</sup> set out to examine the effects on creativity of microdoses of LSD. He and his team tested eighty healthy adult males, who were given either a 10µg dose of LSD or a placebo every third day for six weeks (fourteen doses in total) and then analysed with a battery of creativity tasks including the AUT and RAT. The researchers found no significant effect, despite many participants reporting that they felt more creative on dose days. As Suresh concludes, ‘Laboratory testing conditions may negatively affect ability<sup>77</sup> to detect naturalistic differences in creative performance. Maybe the tests available do not capture the facets of creativity that are anecdotally affected by microdosing, or perhaps the reported enhancements of creativity are placebo effects.’

Whether or not there's any scientific evidence for the benefit to creativity of microdosing, there's no doubt that the recent resurgence of interest in psychedelics is starting to reveal more about the magic that makes up our minds, including our creativity. Examining the impact of these substances on our brain flexibility and creativity gives insight into the significant potential therapeutic gains<sup>78</sup> for those living with depression, anxiety, trauma and addiction. And as we've seen throughout this chapter, where our brain is free of stress, negative rumination and distress, it is already infinitely more predisposed to innovative thinking, playful curiosity and confident creativity. Improved mental well-being and creativity go hand in hand in our brain, whether your intervention of choice is a guided meditation, a walk in the woods, listening to an audiobook with a warming cup of hot chocolate or, if and when it is legalized in the future, a dose of psilocybin.

## Creativity is a whole-brain activity – so connections are key

In October 2024, a paper was published<sup>79</sup> in the neuroscience journal *Brain* that presented further compelling evidence for creativity being the product of activity across a set of interconnected brain regions. 'Unlike motor function or vision<sup>80</sup>, creativity is not dependent on one specific location in the brain,' said Ben Shofty, Assistant Professor of Neurosurgery in the Spencer Fox Eccles School of Medicine in Utah and the senior author of the paper. He and a team of researchers from the University of Utah Health, Baylor College of Medicine in Houston, and Technion (Israel Institute of Technology) set out to demonstrate that creativity was not merely correlated with high connectivity across brain regions, but caused by it. They conducted a small-scale study with thirteen participants that went much deeper into unearthing the source of creativity than previous studies, which had relied on EEG caps or fMRI scans. The team drew their volunteers from a group of people with epilepsy, who were being monitored for seizures by having tiny electrodes inserted directly into their brains across many dispersed regions. Invasive brain surgery is of course not an option for studies on otherwise healthy volunteers; it would not be ethical. But in this case, the researchers were able to piggyback on the routine

seizure-monitoring to stimulate and record specific circuits directly, all while asking participants to take part in mind-wandering and Alternative Uses Tasks.

Participants were shown a blue box shape for twenty seconds and asked what it made them think of. They were then given sixty seconds to reply with a chain of thoughts, such as the sky, kingfishers flying, river plants, fish, oxygen, and so on, before being asked to carry out a standard AUT. ‘We could see what was happening within the first few milliseconds of attempting to perform creative thinking,’ Shofty said. The default-mode network sparked up and then synchronized its activity with regions involved in complex problem-solving and decision-making, as ideas were presumably evaluated for use. The researchers then used the electrodes to temporarily dampen activity in the DMN, which resulted in lower creativity scores on the AUT. Eleonora Bartoli, Assistant Professor of Neurosurgery at Baylor College of Medicine, explained that the findings ‘highlight the causal role of the DMN in creative thinking<sup>81</sup>’. This is the self-same network that, under the influence of psychedelics, generates novel ways of perceiving the world.

What was particularly striking was the role played by increased gamma oscillations. Gamma brain waves are fast – they’re at the opposite end of the spectrum from those lovely slow alpha waves we talked about previously – and in this study they were the ones most profoundly associated with enhanced creativity. Perhaps this isn’t surprising given that creativity involves regions across the brain’s whole connectome, meaning that fast communication would be required to deliver quick innovative thinking and multi-modal computations. What’s fascinating, though, is that scientists have known for over twenty years that increased gamma-wave oscillations are also associated with meditating brains, thanks to tests on Buddhist monks to measure their brain waves while they were meditating.<sup>82</sup> The precise relationship between meditation, mind-wandering and divergent thinking remains elusive, but meditation does appear to play a helpful role in the process. Given its proven benefits for individual well-being, there seems no reason not to investigate its potential advantages for creativity.

In fact, this overlap between mental health and creativity feels like an exciting way to improve both. Alterations to the neural networks that are now known to drive creativity have been discovered in virtually every

psychiatric and neurological disorder, from depression to schizophrenia, frontotemporal dementia and Alzheimer's disease. When depressed individuals, for example, get caught up in repetitive negative thoughts during mind-wandering, that state of negative rumination can lead to feelings of profound distress. If their DMN could be stimulated with psychedelics, electrical activity, or more simply, if they practised meditation, perhaps they could learn to interrupt those negative loops and employ divergent thinking to imagine a new scenario and come up with a different interpretation of their situation. As Ben Shofty says, it's early days yet for practical strategies to boost activity across the creativity circuit, but the potential is clearly there for us to relieve mental suffering and build greater creative brain power at the same time.

## Improvisation: peak creativity?

Have you ever found yourself so deeply absorbed in a pleasurable task that distractions disappear, time becomes irrelevant and you enter an almost meditative state? It can happen when you're hitting balls at the golf range, playing the piano or writing in your journal. Many of us experience it when we're using our body and mind in harmony to do something skilful such as playing a musical instrument or dancing. Most of us have felt it occasionally and long to feel it again. The sensation is known as 'flow' and it's one of the most creative and fulfilling states of mind that any human being can encounter, something like a cross between the focus of a person with ADHD and the immersion in play of a four-year-old. You probably know about it already as the concept has been widely discussed ever since the Hungarian-American psychologist Mihaly Csikszentmihalyi, known as the 'Father of Flow'<sup>[83](#)</sup>, described it in his seminal book *Flow: The Psychology of Optimal Experience* back in 1990.

What particularly interests me about flow is the way it combines some characteristics of convergent thinking, plenty of divergent thinking and a hefty dose of the free-floating liberation our mind experiences during its wanderings, to produce a unique cognitive state. When you're in flow, you're focused but not labouring, free-wheeling but with a purpose. You need a certain level of mastery of a subject to get into flow. A novice can't access it because they're still concentrating hard to master the basics. But



once you've practised enough, you can perform your skill automatically and with grace. You're ready to step into a state of creative flow.

Not everybody does, though, or not consistently. It can be hard to develop the necessary expertise. On the other hand, you can have too much of that good thing. There's a reason that Buddhist meditation teachers value what they call 'the beginner's mind', with all its openness to new ideas. The problem with being an expert, in any field, is that there's always the risk you get rigid in your approach. You end up relying on what works, even if the situation demands a different take. An expert is sometimes so risk-averse that their capacity for creativity diminishes.

As you might expect, there seems to be a sweet spot that some people can hit. They become an expert in a particular field by practising for countless hours to build a bank of knowledge and skill. This means their automatic thinking is finely tuned, but they can still access a playful, childlike state and let those creative juices flow. They become capable of innovating in real time through skilful improvising, turbo-charging their flow state. What's going on in the brain during this process? Can we all achieve it, and more frequently?

No art form is more associated with improvisation than jazz, and in 2024, scientists at Drexel University in Philadelphia conducted a study of the brains of improvising musicians in the hope of uncovering the neural signature for this state of hyper-creative flow.<sup>84</sup> After recruiting thirty-two jazz musicians, covering a spectrum of ability and experience level, the scientists asked them to play and then to shift into improvising, recording their music and measuring the oscillations on the outer areas of their brains via EEG as they played. Afterwards, the participants answered questions to rate the intensity of their flow experience, degree of immersion and enjoyment.

The resultant 192 recorded musical improvisations were then reviewed by four jazz experts who judged the pieces according to their creativity, aesthetic appeal and technical proficiency. This data was then analysed alongside the EEG recordings of the musicians' brain waves. The scientists noted that the musicians' reports of a high-flow state correlated with increased activity in the left-hemisphere brain regions associated with auditory and tactile processing. This suggests that greater engagement with the key senses involved in playing music – hearing and touch – were important for the flow state. Strikingly, there was also decreased activity in



the superior frontal gyrus, a brain region implicated in executive functions and conscious control. It looked as if a temporary lowering of prefrontal cortex activity was helping to reduce the cognitive load and allowing for fluid and intuitive improvisation.

The study found that musicians with greater experience were more likely to enter a high-flow state, and in a more intense way, than those who were still relative novices. But there was a counter-intuitive finding alongside this, which perhaps nods to the complexity of creativity. These experienced musicians had a distinct neural signature during flow states: reduced activity in parts of their default-mode network, the circuit associated with mind-wandering, imagination and the starting point of creativity. The reduction in DMN activity suggests that, for experts, entering a flow state means moving away from introspection and towards a more outward-focused engagement with the task. Attaining that singular combination of an almost Zen-like focus with intuitive flow requires, at a neural level, not only the ability to engage deeply with the task at hand but also a ‘letting go’ of conscious control. This enables the specialized neural circuits developed through extensive practice to take over, guiding the creative process more efficiently and intuitively. The mastery implied in this flow state appears to transcend genres. In 2012, an fMRI study of freestyling rappers revealed a similar neural shift<sup>85</sup> – the prefrontal cortex brain areas, including the superior regions, responsible for executive functioning and regulation, showed a reduction in activity as the rappers transitioned to improvisation.

When John Kounios, Professor of Psychology at Drexel University and author of the jazz study, was asked to comment on the takeaways for those of us who would like to emulate these master musicians, he pointed to the necessity of extensive ‘practice to build up expertise coupled with training<sup>86</sup> to withdraw conscious control when enough expertise has been achieved’. He added: ‘If you want to be able to stream ideas fluently, then keep working on those musical scales, physics problems or whatever else you want to do creatively – computer coding, fiction writing – you name it. But then, try letting go. As jazz great Charlie Parker said, “You’ve got to learn your instrument. Then, you practice, practice, practice. And then, when you finally get up there on the bandstand, forget all that and just wail.”’

The idea of letting go without fear of the consequences, of being confident enough to lose the inhibitions that might otherwise impede our

creativity, seems crucial to attaining a high-flow state. Having done the necessary preparation, we need to feel sure of our ability and able to enjoy it, rather than anxiously directing our cognitive energy to monitor how others might perceive it. Perhaps this insight partly explains why mindfulness-based meditation is helpful for creativity, since it can reduce our sense of ego, making us less self-critical, self-conscious and worried about what others think.

Hannah Fry, Professor of Public Understanding of Mathematics at the University of Cambridge, said something about self-expression that I find both wise and liberating. ‘When we allow ourselves to actively let go<sup>87</sup> of the thoughts that keep us in control, the brain’s specialised networks for self-expression are able to take over and fly. The potential is there in all of us. Contrary to what some may think, you don’t need to be a creative genius to reach this freeing level of enlightenment ... When we give ourselves permission to be playful and let go of inhibition, beautiful things happen.’

## Creatively fit for the future

Human beings are gloriously and limitlessly creative. As a group, we’re standing on the edge of a major shift in creative potential. If we can step with confidence into the full extent of our powers and learn to work together to harness the range of talents at our disposal, there’s nothing we can’t do. As individuals, it’s totally possible to exercise and enhance our imagination, originality, curiosity, expertise, resilience and open-minded confidence, whatever our age, background or genetic make-up. That too many of us don’t believe ourselves to be creative is almost certainly the biggest block to our individual and collective creativity, and it’s being stoked by paranoia about AI having already rendered our creativity obsolete. Nothing could be further from the truth.

If we are to flourish into the future, it is imperative that the imaginative, innovative, creative, problem-solving flair, which has been so fundamental to our species’ evolution and so world-altering for our social and cultural development, is not lost. I believe we’ve been artificially separated from too many of those innate skills. The division between sciences and arts in our education system has become rigid and prevented interdisciplinary thinking. For the last two decades, science and engineering have been pitched against the arts and humanities and come to dominate our schools and universities

as well as the way we think about creativity in a commercial context. Great and innovative work has of course been done across all subjects and sectors, but I worry about the artificial distinctions between them and the restrictive nature of the labels we apply to our extraordinary spectrum of creative human talent.

I suspect that part of the problem is that scientists have traditionally studied intelligence without looking at creativity, and have systematically misunderstood and undervalued it in the process. The standard IQ test makes no attempt to measure it, when, as we've seen throughout this chapter, creativity's cognitive components underpin IQ performance and every other sophisticated trait, skill and behaviour you care to mention. Institutions in government, education and industry all over the world have swung away from valuing core creative skills. Perhaps that's connected to the mythmaking aura of genius that tech businesses have so carefully cultivated for themselves. Perhaps it's both product and cause of individualistic capitalist societies. Whatever the reasons, I believe the development of AI is pushing us to swing that pendulum back.

Barbara Sahakian is Professor of Psychiatry at the University of Cambridge and co-author of *Brain Boost: Healthy Habits for a Happier Life*. She and her colleagues wrote in 2021 in *The Conversation*: 'IQ is often hailed as a crucial driver of success<sup>88</sup>, particularly in fields such as science, innovation and technology. Many people have an endless fascination with the IQ scores of famous people. But the truth is that some of the greatest achievements by our species have primarily relied on qualities such as creativity, imagination, curiosity and empathy.'

Now that we're under pressure to consider how to live intelligently alongside AI, we're thinking more laterally about our very considerable innate powers. Ironically, that might be nudging us to behave, in some ways, more like AI. When we're mind-wandering or dreaming, we gain access to some of the vast amount of information held in our brain that's usually unavailable. The brain's innate delight in creativity seeks out ways for us to access that infinitely greater data set and come up with novel solutions. I love the paradox that our anxiety about AI's creativity might push us to be more creative in a way that is both essentially human and reminiscent of one of our most creatively inspired inventions. Even if this paradox is a mere invention of my storytelling brain, I'm taking pleasure in the idea. Either way, it's time we started to appreciate our creative skills, to

see them as key traits underpinning our survival, to nurture and above all to enjoy them.

## **|EXERCISES|**

A brain fit for the 21st century is ... teeming with creativity and imagination

- Feeling stuck on a problem? In need of inspiration and a new way of thinking? Take yourself outside for a walk to stimulate alpha waves. They are the slowest of the electrical oscillations in the brain, associated with calm and creative problem-solving, and are enhanced when we're in a natural environment.
- Read fiction and immerse yourself in a different reality. Listen to audiobooks and imagine the detail of each scene. Whether you're reading children's books with your family or volunteering to read aloud to local primary-school children, the benefits for you and them will be immense. You could practise storytelling, either in written form or orally in a group, such as over a meal or around a campfire.
- Give yourself time to indulge in daydreaming. Allow your mind to wander without restraint and, if possible, without your even being aware of where it's taking you. This is important for adults, but also for children. Provide them with opportunities to daydream rather than back-to-back structured activities under supervision.
- Incorporate play into your life. Experiment to discover your play personality. Allow yourself to be more childlike, seeking out activities that serve no purpose beyond escapist fun (if you will ignore the irony of my prescribing this as a way to enhance your creativity). Get stuck in and play.
- Cultivate flow through improvisation, or simply through immersion in your latest creative play-based pastime. It requires expertise to create the foundation for flow, so practise, practise, practise, and then try to let go of any inhibitions, anxiety or fear of how others might perceive you. Let the creative juices flow!

## Thinking Longer-Term

IN THE ARCTIC CIRCLE, WINTER TYPICALLY lasts for nine months of the year, and for much of that time people live in the tundra of 24/7 darkness. The Inuit have adapted their lifestyle accordingly. A multigenerational community group takes time to sit in ‘Qarrtsiluni’ (pronounced *kartz-sih-loo-nih*), which translates as ‘waiting for something to happen/burst forth’. They wait in expectant yet patient quiet for hours at a time. No lamps, no light. No chat. Just openness to what might be, and connection to each other. Qarrtsiluni serves myriad purposes, from processing shared grief to marking the beginning of a festival meal or the longest period of winter. The Inuit believe that in the silence of group thought, the air of anticipation helps promote creativity and nurture wisdom. Out of the darkness comes inspiration, streaming into their collective consciousness and underpinning their survival in this hostile environment.

In the Western world we have allowed our ability to sit, wait and think together to lapse. We’re busy buzzy people, inundated with noise and distractions, armed with lists of largely inconsequential things to do to serve our individualistic lives. It’s become easy to overlook or hide from the more significant but also more complex and challenging longer-term projects that give our own lives and our social groups coherence and purpose. We end up caught between our deep hunger to create meaning and our aversion to doing the cognitive work required. Can we find a clever way out of this bind? Can we carve out time to practise the patient but productive waiting of Qarrtsiluni so that we are not slaves to our immediate desires but can work on behalf of our future selves, our community and even our descendants?

I’m convinced we can. While our brain may be innately in thrall to short-term gratification, it also evolved to be capable of making and

implementing grand plans over an extended period. If the balance is a little out of whack for many of us, that doesn't mean we can't adjust it and relearn how to think more broadly and longer-term.

The key brain region involved in longer-term thinking – in delayed gratification, reflection, resilience, informed risk-taking and, ultimately, expanding the perception of timelines to consider our collective legacy – is the prefrontal cortex. Scientists believe that during the last 5 million years of human evolution<sup>1</sup> the brain has tripled in size. Size isn't always everything,<sup>2</sup> of course, but perhaps ratios are. The prefrontal cortex, which sits behind our forehead,<sup>3</sup> is thought to have increased at twice the rate of the rest of the brain. In humans it represents up to 29 per cent of the surface of the cerebral cortex and just 17 and 11.5 per cent of that in the chimpanzee and the rhesus monkey, respectively. It now takes up around 10 per cent of our total brain volume, occupying a larger percentage than in any other animal. Although we might not always feel convinced of its efficacy when we look at the state of our species and the planet we inhabit, the prefrontal cortex directs our so-called 'executive functions' – curbing short-sighted, reflexive or impulsive behaviours so that we can prioritize and plan, make decisions and problem-solve with self-control and long-term goals in mind.

In this chapter we will examine how this short-term versus long-term thinking plays out, and the risks of swinging too far away from thinking long-term. What is the neurobiology of developing and implementing longer-term views rather than falling prey to short-term gratification? How can we increase our ability to pause, reflect, persist and to evaluate short-term versus long-term rewards and risks? How can we expand our own cognitive timeframe, considering future generations and even our species' ongoing evolution?

Human beings' ability to imagine hundreds of years ahead and think on behalf of the generations to come has underpinned civilization-building projects from the construction of Egyptian pyramids and medieval cathedrals to the transmission of indigenous culture via oral storytelling both today and since ancient times. It is a smart and desperately needed counterpoint to the short-term, shortsighted way of being that impels us to burn through our days and the Earth's resources. How can this so-called 'cathedral' or 'seven generations' thinking be fostered? We'll see that a key

component of thinking longer-term is doing so more broadly, considering other people as well as ourselves, hence in this chapter we'll also look at prosocial thinking, both as a form of personal insurance against future misfortune and as an expansion of our circle of care.

## A successful life depends on longer-term thinking

While in theory we know that long-term thinking is valuable, it often feels intangible compared to the concrete value (and appeal) of its short-term equivalent. It is a skill that we have to learn in childhood and adolescence and it takes practice to implement properly. By the time we reach full cognitive maturity<sup>4</sup> (typically by our mid-twenties), most of us will have begun to grasp that anything worthwhile in life, whether it's a relationship, a project or a goal, is likely to be complex, involving multiple steps over different stages. It will take time, skill and sustained effort to pull off, so patience and resilience are key. That goal or project will probably also require positive input from other people, so we need to think about them as well as ourselves.

We will also have learned that, conversely, giving in to instant gratification may feel rewarding in the moment but it comes with risks and trade-offs. It won't always be a smart move. We need to figure out how to pace ourselves and anticipate how events are likely to play out, planning accordingly. Sitting down to finish that long-overdue report that your boss desperately needs, for example, rather than heading to the canteen to get yet another sweet treat as a distraction. Putting aside money each month for next year's family holiday rather than buying on impulse the latest gizmo or newly released and much-coveted pair of shoes. We must learn to balance short-term gains and passing pleasures with the slower rewards of the long game, and continue to consider with empathy other people's points of view, long-term needs and goals.

None of this is easy but, as we've seen, human beings have an advantage: a highly evolved prefrontal cortex. Although, given that this region doesn't develop fully or become knitted into the brain's connectome until our mid-twenties, it's no surprise that long-term thinking takes practice or that young people are not great at it. They're wired for novelty-seeking because



their biological imperative is to go out and explore the world, gathering all the information and acquiring all the skills that will eventually accrue into wisdom. That makes them more reckless but also more creative, as we've seen. As ever when it comes to the marvels of a healthy, flourishing human brain, it's a case of swings and roundabouts, benefits and drawbacks. And clever workarounds.

While cognitively mature adults know the power and value of long-term thinking, it still needs to be practised because our brain's innate bias in favour of immediate reward is very powerful. Behavioural economics (psychological analysis of economic decision-making) has coined the phrase 'hyperbolic discounting' to describe our typical preference for a smaller reward sooner rather than a larger one later. When offered the choice between £50 now<sup>5</sup> and £100 in a year's time, for example, many people will choose the immediate £50. Businesses have dreamed up endless ways to capitalize on this hard-wired preference, which also plays out in terms of our health and lifestyle choices. How many times have you rejected the idea of going for a run in the cold (even though you know it will pay health dividends in the long term) in favour of the immediate reward of sitting cosily on the sofa, watching Netflix with a sugar-rich takeaway (even though you know it may impair your sleep that night, impact your mood tomorrow and your health in the longer term)? We've all been there. Repeatedly. And yet if you've ever managed to establish an exercise habit or finally got round to sorting out a pension, you'll know that such efforts do reap rewards. It's tough, but worth it.

The value and necessity of this cognitive capacity to think long-term is increasingly being talked about for individual and collective health, wealth and success. Dorie Clark is Executive Education Professor at Columbia Business School and the author of *The Long Game: How to Be a Long-Term Thinker in a Short-Term World*. As she has observed: 'It's human to want short-term results<sup>6</sup> – to see that our efforts are working, and paying off in real time. But the truth is, some of the most meaningful outcomes ... take time, often far longer than we might want. That's what playing the long game is all about. It's about being willing to make sacrifices in the short term and persevere, even when things are difficult or challenging or it's unclear that you're making progress ... That's how you put distance between yourself and the competition and create the life and career you want.'

Businesses like Google have pioneered ways of working that try to rebalance long-term and short-term thinking to maximize the benefits of both. Some of them have become management-speak clichés (‘fail fast, learn fast’), but there’s no doubt that they’ve also delivered huge innovation. Google encourages employees to spend up to 20 per cent of their time<sup>7</sup> on speculative projects, for example, conferring with others to explore open-ended ideas. This might not immediately result in anything concrete but has occasionally led to a highly innovative and lucrative product, including Google News and Gmail. It’s never time wasted because it sparks ideas and builds trust between team members, all of which might eventually come to fruition in some form.

The horror of wasted time resonates whether you’re a busy executive running a team at a corporation or a hard-pressed college student or working parent. Time has become the ultimate luxury in our frantic lives because it feels so scarce. Demands are of course unavoidable given that we all have to earn a living and fulfil our responsibilities at home and at work, but the intense social and cultural pressures that ramp up our short-term thinking at the expense of our capacity to explore, persevere and plan for a successful future can and must be resisted. What are the lessons from neuroscience that will help us to plant seeds for our future selves, so that the years do not merely fly by in a haze of short-term reward? How might we dedicate 20 per cent of our time not only to ensuring our own future well-being and success, but also to building our personal and collective legacy? Even though we live in a capitalist world of overconsumption, can we train our brains in the reflective ways of Qarrrsiluni?

## Delayed gratification: the foundation of longer-term thinking

The Stanford marshmallow test<sup>8</sup> must be one of the most famous experiments ever carried out by behavioural psychologists. Back in 1970, a team led by Walter Mischel, Professor of Psychology at Stanford University, ran a series of tests on four-year-olds that introduced the phrase ‘delayed gratification’ to the world. The experiment’s results enshrined the ability to wait for a greater future reward rather than accepting a smaller one now, as one of the foundational behaviours for a successful life. Its

premise is simple but challenging, especially for small children, whose executive functioning is far from fully developed.

The design of the experiment is simple: a child is offered the choice between one small but immediate reward (either a marshmallow or a pretzel, depending on preference), and two rewards if they wait for fifteen minutes. The child is left alone in a quiet room with the single reward and no distractions, with the clock ticking. When the researcher returns, and if the reward is untouched, a second treat is added as promised and the child can eat both immediately. Results were clear then and have been replicated many times since: while some children wait, the majority do not. Children who can distract themselves<sup>9</sup> with their imagination, or simply by covering their eyes so they're not looking at the treat, were far more successful than those who deployed no such strategies. This pivotal study has yielded a slew of publications which show that the children who can wait have a range of better life outcomes, from greater educational success as adolescents<sup>10</sup> to increased social competence and ability to deal with frustrations and stress, and even healthier BMI ratios thirty years later.<sup>11</sup>

Back in 1970, the launch of the Human Genome Project lay twenty years off, but we now know that genes play an important role in an individual's ability to delay gratification; heritability is estimated to be around 50 per cent.<sup>12</sup> Lacking this genetic signature has been linked to myriad conditions,<sup>13</sup> from ADHD and schizophrenia to obesity and major depression, and addictive behaviours like smoking. Bad news for the 50 per cent of us in this boat. Tests on adults have revealed that specific brain regions are involved in the ability to delay,<sup>14</sup> the brain's prefrontal cortex being more active in those scoring highly on this, and the ventral striatum (an area that includes the nucleus accumbens and is linked to addiction) more active in those with a low score.

So what exactly is going on in the prefrontal cortex that boosts the ability of those 'high delayers' to metaphorically, or even literally, sit on their hands and resist life's marshmallows? The key mechanism by which impulsive actions are curbed takes place within inhibitory stop-signal nerve cells, also known as GABAergic neurons – so called because they release gamma-aminobutyric acid (GABA), one of the brain's chemical messengers, which dampens the nerve cells' ability to send or receive messages, slowing down cellular activity and producing a calming effect.

The prefrontal cortex is densely populated with these nerve cells, whose role is to act as a brake on excitatory signals zipping along the reward and motivation systems. They buy us a little bit of time to think. The prefrontal cortex also has a role to play when we do slip up and enact detrimental short-termism. As the brain region strongly associated with feelings of guilt and remorse,<sup>15</sup> it helps deter us from behaving in the same way in the future.

One neurological explanation for alcohol being so widely enjoyed is precisely because of its action on these cells in the prefrontal cortex.

Alcohol switches off the GABAergic stop-signal nerve cells<sup>16</sup>, which means the underlying circuits no longer have the brake system applied and are free to run their signals around the brain. That's why being tipsy generally lowers anxiety and awareness of social pressure to behave in an appropriate way. We relax, but, as we drink more, our judgement becomes impaired; we might start to speak and act without considering the consequences or filtering the content. Being drunk means we're dancing to the whims of excitable short-term thinking, which might feel like a relief or a buzz initially, but can have some pretty disastrous repercussions if it goes too far.

Determining whether a person has the genetic signature of a high or a low delayer allows scientists to predict with considerable accuracy whether they will fall prey to some of the longer-term manifestations of short-term gratification: obesity, for example, which epitomizes the triumph of short-term gratification over longer-term health benefits. When combined with an analysis of activity in different brain circuits involved in impulsivity and control, as well as the results of investigations into reward and inhibition behaviours, scientists can identify with 64.4 per cent accuracy which individuals will go on to develop obesity.<sup>17</sup>

It's not just genes that play a role in our ability to delay gratification, though; the environments we grow up in have an impact too. That's something that the 1970 Stanford experiment inadvertently revealed but didn't fully explore. There was always a moralizing tone to the way the data was interpreted in some quarters. Self-control is after all a highly prized character trait and its opposite is regarded as a weakness, even, it seems, in children. Subsequent analysis of the results advanced a different interpretation,<sup>18</sup> suggesting that if a child came from an unpredictable

home environment or one where treats and perhaps even food were scarce, it was a highly rational choice to opt for the reliable immediate reward. After all, if you think someone is going to come and steal it from you, or renege on their promise to give it to you, it makes perfect sense to eat it immediately rather than wait and risk ending up with nothing. The saying ‘A bird in the hand is worth two in the bush’ springs to mind here!

Parents’ educational level and socioeconomic status play a significant part in the cognitive traits of their children, just as much today as they did back then. In a recent study of 2,000 Singaporean children,<sup>19</sup> those whose parents came from more educated backgrounds showed greater self-restraint and willingness to delay their gratification in their preschool years, while children of less educated parents started delaying gratification at an older age. This study also confirmed the correlation between the ability to delay gratification at a younger age, better working memory and self-control, better academic skills and fewer behavioural and emotional problems two years later.

Fortunately, this foundational cognitive trait is not fixed by the accidents of our genetic inheritance and birth; it’s highly susceptible to ongoing environmental pressures, which means that positive interventions can give a big boost to children’s abilities. In a study from 2020, the findings of the 1970 Stanford marshmallow test were re-analysed<sup>20</sup> using a data set of around 1,000 children (this time based in America with the majority of participants being of white ethnicity). This highlighted the important role of social support in developing the capacity to delay gratification. Those children who had a greater network of people they felt they could call on for help were more likely to be able to wait and reap the greater reward. In another study, manipulating the perceived reliability of the person<sup>21</sup> promising the reward affected children’s willingness to wait for the marshmallow, or a similar enticing treat, adding weight to the idea that social support helps buffer against short-termism. This is highly likely to be the case in adults as well as children: experimental evidence suggests adults are less willing to wait<sup>22</sup> for hypothetical monetary rewards from untrustworthy individuals relative to trustworthy ones. Resisting impulsivity and short-term thinking is cognitively demanding; it’s hard work. All cognitive work is easier when we’re not stressed, tired or hungry,

when it becomes doubly hard to overcome our innate proclivity to eat the damn marshmallow!

Dr Laura Michaelson of the American Institutes for Research in Chicago is the senior author of the 2020 study. As she explained to me: ‘These findings depart from prominent interpretations<sup>23</sup> of the factors driving children’s delay of gratification. Children are not simply operating on willpower alone. Their beliefs about whether and when the future reward will be delivered as promised – which are shaped by the people, settings, and objects in their environment – also matter. A child may be perfectly capable of waiting, but opt not to when delaying gratification is not rational or warranted. Efforts to intervene on children’s seemingly impulsive behaviour may therefore be best directed toward improving the strength and stability of the systems and communities they rely on, rather than their core capacity to resist temptation.’

As further studies have been carried out over the years, they’ve revealed fascinating cultural nuances to the findings about how delayed gratification develops and is applied. Children in Japan, for example, wait three times longer for food<sup>24</sup> than for gifts, whereas children in America wait nearly four times longer for gifts than for food. Dr Kaichi Yanaoka of Kyoto University and Professor Yuko Munakata of the University of California, Davis, led a study of 138 children in the two countries (80 children from Japan, 58 from the USA) that revealed this cultural effect. It transpires that Japanese children are expected to wait to begin eating at the meal table, but delaying the unwrapping of gifts at birthday or festive parties is not the norm. In America, the opposite societal expectation is set. According to Yuko: ‘The ability to delay gratification, which predicts many important life outcomes, is not just about variations in genes or brain development, but also about habits supported by culture.’

It’s over half a century since the marshmallow test was devised, and while the interpretation of its original findings has been critiqued and finessed, the data sets have also been endlessly replicated. The basic conclusion remains the same: the ability to delay gratification from a young age is a resoundingly positive trait that supports the development of many other desirable cognitive skills and life outcomes. The reassuring amendment to this is that we can train our children to be better at it. As Dr Michaelson concluded: ‘These findings underscore the potential to improve



children's delay of gratification by exposing them to groups and cultures for whom waiting for rewards is valued and regularly practised.'

## Pause: the time-expanding power of thinking slowly

If learning how to delay gratification is one of the most important cognitive feats of childhood, adults can't afford to assume that the skill, once acquired, will look after itself. Even without the perils of our highly distractible environment, long-term thinking will always be in tension with our evolved preference to scratch the dopamine itch whenever it occurs. Luckily, there are other cognitive behaviours that we can develop and practise in order to help us to think strategically about the future. Being able to vary the speed of our thinking is one of them. If we can slow down our mental activity so that we can reflect rather than react, it's much easier to resist impulsive behaviour and take time to scan the horizon for information to enable us to make a more considered move. Slower thinking begins with a pause, and the ability to be present in the specific moment. Pausing often feels difficult when we're consumed with busyness, but it is hugely beneficial as it allows us to experience reality with more intensity and fidelity, which helps us to think calmly about the future.

Psychologist Dr Steve Taylor<sup>25</sup> is based at Leeds Beckett University and is the author of *Time Expansion Experiences: The Psychology of Time Perception and the Illusion of Linear Time*. He's an advocate for the benefits of living and thinking slowly, one of which is being able to access a time-stretching effect in which we notice and appreciate more of what we're experiencing. Mindfulness-based meditation is one of the most effective and accessible ways to experience this time expansion (and much more appealing than some of the other altered states he examines in his book, such as being involved in an accident). It's also relatively quick to produce measurable benefits, as one study demonstrates. Participants were asked to meditate<sup>26</sup> for thirty minutes a day for a week and then shown two short documentary films, each lasting five minutes. When the volunteers were asked to estimate the length of the films, the times they guessed were significantly longer than those estimated by a control group that hadn't practised meditation. It seemed that meditating had expanded the first



group's perception of time. Other studies have shown that meditators<sup>27</sup> with years of practice experience time as ample and expansive, but a pleasurable sense of slowing down time<sup>28</sup> might be available even to beginners.

There are so many cognitive benefits to mindfulness-based meditation, but I'll admit to a particular fondness for the way it can usher you into a layered state of consciousness where time is no longer linear. Meditating allows us to exercise cognitive restraint and undo autopilot thinking, since the more aware we are of our autonomic reactions to impulses, the better prepared we will be to resist them.

Even on a molecular level, humans have evolved to reap benefits from being slow. In a recent study published in the journal *Nature*, researchers examined molecular-level differences<sup>29</sup> in the way cells reproduce, comparing human cells and single-celled bacteria, our exceedingly long-ago ancestors. They wanted to compare the level of accuracy with which cellular changes took place in each organism, so they examined a basic translation reaction, which underpins the ability of all living things to create functional proteins from the information held within genes. Ribosomes are the organelles (specialized subunits within a cell, a bit like the organs in our body) responsible for this process, whether in single-celled bacteria or in highly complex human beings, but in our case their machinery operates much more slowly – by an order of magnitude – compared to that of the bacteria.

This tells me that at every single stage in our evolutionary journey, slowness has been preferred for this particular process, which makes sense because it allows for much greater fidelity as genes are copied. That in turn reduces the chance of errors creeping in that might eventually lead to harmful mutations and over-growth. I find it charming that the benefits of working slowly with long-term consequences factored in are visible at every level of human biology, from gene expression to complex behaviours such as meditating. A slower, more reflective approach also provides a useful counterweight to our enjoyment of speed and instant gratification.

Our world appears to be evolving ever faster under pressure from technological advances. The term 'half-life' was coined by atomic and nuclear physicist Ernest Rutherford in 1907 to indicate the time taken by a radioactive isotope to reduce to half of its original value, and measuring this

process was initially used to determine the age of rocks. The phrase is now being applied to everything from new technical innovations to knowledge itself. In this context, something's half-life is the time it takes to lose half its currency before it is innovated away, and this is speeding up exponentially as AI accelerates disruption to the status quo. The half-life of skills has been estimated at five years,<sup>30</sup> technical skills at a mere 2.5. The half-life of competitive advantage is less than eighteen months for S&P 500 companies in the USA, and the average CEO tenure of these companies has decreased by 20 per cent, from six years in 2018 to 4.5 years today. The half-life of medical knowledge is twenty-four months and is projected to reach one hundred days by 2027. Recently evolved AI systems have ramped up this process significantly and don't suffer from fatigue or overload as we do.

How can we cope with such rapid technological and societal change? Perhaps stretching our perception of time will help. Seeking ways to relax, be present in the moment and notice the world around us might take the pressure off our thought-churning brain and create the right conditions for reflection. And rather than lament our individual inability to process data as fast as AI, perhaps we would do better to learn to appreciate the increased fidelity that comes with human slowness. To appreciate that there is untapped potential for clarity, insight and creativity when we lean into thinking slowly.

## To grit or quit? How to persevere (and when it's smarter not to)

Anyone who has ever worked towards a significant goal knows that persistence is key to eventual success but there will be times when persistence alone is not enough, and others when it's downright counter-productive. Sometimes the real wisdom lies in letting go. The clever bit is figuring out when to grit, to keep on going, and when it's best to quit. Say you're standing at a bus stop, waiting for a bus. At first you're hopeful that it will be here any second but, as the minutes tick by, doubt creeps in. Should you keep waiting or is it smarter to start walking or call for a ride? 'It's a classic dilemma,'<sup>31</sup> says researcher Joe Kable from the University of Pennsylvania, who studies decision-making and perseverance. 'Do you

persist with the belief that the bus is on its way, or do you cut your losses and move on to something else?’

We often see persistence as a moral good and quitting as a failure, but it is not as black and white as that – either in life, or in your brain when it’s weighing up the options. Figuring out whether to grit or quit requires complex mental calculations based on potential value, reward, risk, the specific situation and past experience. It’s never a simple matter.

When I was working with a pharmaceutical company more than twenty years ago, there was a standard test used to assess whether a new drug might show efficacy as an antidepressant. It was called the forced swim test. The premise is simple – you give a mouse a dose of your candidate drug and place it in a container of water, with no platform or way out, then record how long it will expend energy doing laps as it searches for an escape. The rationale is that the longer the mouse swims, the more promising the drug. Swim time is viewed as a proxy for perseverance, or grit. If the mouse spreads itself out and floats, it has succumbed to depression and given up. Faster quitting suggests a less efficacious drug.

At the time I questioned not only the ethics of this test but its validity too. Surely the floating mouse is the clever one? Perhaps it is not merely a quitter but has intelligently assessed the situation, realized there is no escape route and consciously decided that, in this environment, the best thing is to simply float and wait till the researcher picks it up? The pharmaceutical companies did not agree with me. Two decades later, in March 2024, the journal *Science* reported on the mounting pressure to ditch this test<sup>32</sup>, driven by scepticism about what we can usefully learn about depression from the mice’s behaviour and a growing conviction that its assumptions were too unreliable to justify the stress to the animals involved.

The neuroscience underpinning whether we grit or quit is a fascinating field that’s gaining traction and producing results that have implications for all of us. In 2025 Joe Kable and colleagues published a study<sup>33</sup> in the *Journal of Neuroscience* showing the role of the prefrontal cortex in the dynamic relationship between gritting and quitting. They were especially interested in the circuits influencing patience and adaptability.

The team carried out a small-scale human study on 49 people. (Of the initial participants, 31 had brain lesions, and were grouped by the different affected regions of their frontal cortex – the wider region of which the

prefrontal cortex is part. Only 28 of them were included in eventual analyses because lesions in the other three people extended beyond the frontal cortex. There were 18 healthy individuals in a control group without lesions who were matched in age and educational background to other participants.) The researchers gave everyone a series of decisions about when to 'cash out' coins that increased in value over time. Some coins matured quickly while others required a longer wait, depending on the task condition. In essence, the scientists created a situation where persistence didn't always pay off, and termed the different responses as either a 'high-' or 'low-persistence' condition. The main difference between the two was in how wait times were distributed: waiting always paid off in the first case but paid off only for a short time in the second case, where after a few seconds quitting was the more lucrative choice.

What this meant for the study participants, who wanted to accrue as much financial reward as possible, was that, in the high-persistence condition, always waiting until the coin reached its maximum value was optimal. In the low-persistence condition, if the coin did not mature within the first couple of seconds, it was better to stop waiting. Participants weren't told about this in advance, forcing them to learn from experience.

Joe and his colleagues found that participants with brain damage in the ventromedial prefrontal cortex (vmPFC) waited less overall. This region is implicated in decision-making and future planning, including the assessment of risk, the inhibition of emotional response, and self-control. People with lesions in this region were much less able to see the value of waiting patiently. However, participants with lesions in the dorsomedial PFC or anterior insula (located towards the front of the insula cortex) showed a different pattern of decision-making. They were more patient and waited slightly longer overall, though for about the same length of time in both conditions as they failed to distinguish between situations where persistence was advantageous and those where it wasn't. They couldn't learn from their past experience of when it was best to quit. 'It wasn't just a matter of self-control,'<sup>34</sup> Joe says. 'These participants couldn't adjust their strategies based on feedback from the environment, particularly from experiences where quitting was the better decision.' By contrast, the individuals in the control group, without lesions, were able to both wait patiently when that was the best strategy and to pivot and update their thinking when the situation changed.

This study highlights how crucial it is not to treat persistence as inherently better regardless of context. Figuring out when it is smarter to pause and adapt rather than blindly continue is the sort of elegant decision-making that requires a fine balance between interacting brain regions. I try to bear it in mind when I'm faced with a situation like the bus-stop dilemma. The questions become: should I persevere *in this environment*? What is the potential value in doing so? What about the risks? The study also foregrounds the importance of being not just patient but also adaptable. So the question there is, *given past experience*, would I be wiser to give up or continue to invest my time and energy? Such complex calculations will require work across the prefrontal cortex and deep into the anterior insula, which, as studies on intuition and interoception have shown, is involved in picking up on signals inside our body that we might not be conscious of, tapping into the knowledge represented by a gut feeling or a heart flicker. Once again, we see that any complex cognitive process – including figuring out when to persist, pivot or simply give up – requires widespread effort and connectivity across the entire brain and body too.

As for what helps and hinders our ability to persist or pivot when necessary, I was intrigued by a study that was published in 2025 by Misha Ahrens<sup>35</sup> and colleagues at Howard Hughes Medical Institute in the US. Rather than mice, the study used zebrafish to carry out a forced swim test in a virtual-reality environment that exposed the fish to different wave patterns simulating backward motion or being stuck in the same place. The former encouraged the fish to try harder to swim, the latter inclined them to be passive before giving up. In swim tests on rodents, scientists have observed that administering a dose of glucocorticoids (a stress-inducing substance) repeatedly over time will increase immobility<sup>36</sup> – being stressed makes the mice give up much more quickly in the 'stuck in place' paradigm. This is what happened to the fish too: being exposed for forty-eight hours to hydrocortisone (a type of glucocorticoid) increased their so-called 'futility-induced passivity'. The scientists also wanted to find out what happened if they administered a dose of ketamine (a psychedelic relaxant). The ketamine reversed the cortisol effect: the fish on ketamine kept on swimming whatever the wave patterns to which they had been exposed.

This doesn't make me want to get hold of some ketamine, but it does remind me that stress can have a profound impact on the ability of any animal to carry out the delicate task of evaluating value, risk, and learning

from experience. We saw back in [Chapter 1](#) that fear makes it all but impossible to think long-term due to its effects on the nervous system, and that those effects kick in very quickly. With stress, the negative impact can be just as devastating, though it typically takes longer to be felt. Small amounts of stress can be highly motivating, but chronic long-term stress might well alter our ability to assess the relative merits of gritting or quitting. Unfortunately, it's endemic in the environment for many of us, which is why we'll be returning later in the chapter to look at its effects and how we can mitigate them.

## The art of the pivot – or why unlearning can be a power move

Persistence remains an essential skill as we train our brain to be fit for the future, but there's an argument for saying that graceful pivoting is now even more important. Even if we master the ability to slow down our thinking to cope with the accelerating world, we will also need to be agile. And here, once again, there's a paradox. Just as planning for the future will increasingly depend on being able to pause in order to fully inhabit the present, so agility will come to depend on consciously stripping away outdated skills rather than endlessly acquiring new ones. The acceleration of the half-life of everything means that our knowledge, thinking and skill sets might need regular radical pruning rather than just trimming and layering with more ideas over the top. For those of us who are accustomed to regarding the accumulation of education, learning and information as a self-evident benefit, that might feel counter-intuitive.

Humans love learning new skills and adapting their thinking, a gift that, as we now know, is supported by our brain's capacity to forge new synapses (neural connections) throughout our lifespan. This neuroplasticity can create highly complex neural networks but also gives us the ability to discard obsolete pathways in our brain. At certain periods in our development, in fact, discarding rather than layering and branching becomes the dominant way in which the brain reshapes itself, by eliminating neural networks. We remove old ways of thinking to make way for new ones. Synaptic pruning occurs throughout our lifetime but particularly at two key periods during the first two decades: early childhood



as we learn, and unlearn, how the world works, and again at adolescence. During this period, synaptic pruning turns an endlessly branching network that has prioritized the gathering of information into a streamlined one that will be fit for purpose in the next life stage.<sup>37</sup> Outside of these two periods, though, complexity is preferred. We may pay lip service to the ideal of simplicity as a virtue in design but there is a bias in our brain (and, I would say, in organizations) against subtraction and in favour of addition. We tend to tinker with systems (and neural circuits) rather than prune them back entirely and start again. We worry about sunk costs and inadvertently getting rid of something valuable. Could we not simply renovate and upgrade what we already have?

As well as our fondness for adding rather than taking away, we are also prone to compulsivity – doing the same thing over and over again in search of comfort, stimulation or because we're stuck on autopilot thinking and haven't paused to consider a different course. Grittiness is an essential element of long-term thinking, to be sure, and has often been lauded as a virtue, but if this tips into compulsive behaviour there's a risk of it ending in the most unhealthy of short-term thought patterns: addiction.

It's a challenge to our elevation of perseverance as the better option by default to admit that, sometimes, starting again from scratch is the smarter choice. Whether we're trying to tackle a harmful way of thinking or a failing project at work, whole or partial elimination of behaviours is sometimes the most appropriate course of action – otherwise we risk getting mired in a bog of the wrong ideas and irrelevant information, or worse, being pulled under by our own compulsions. Pivoting (gracefully or otherwise) becomes impossible; we get locked into perseverance even if we sense that it's no longer working for us. In this context, rather than trying to absorb more information or learn more skills, it would be smarter to ask what we can discard. What can we choose to unlearn?

In neuroscientific terms, eliminating existing behaviours might mean recovery from addiction for an addict or healing for someone suffering with PTSD. Eliminating brain connections helps to remove learned behaviours, memories, identities or habitual impulses that are harmful. Over time, as new neural circuitry becomes established, it can become a highway for information-processing to create beneficial new habits and different behaviour. This is why efforts at healing from trauma, unlearning unhealthy



associations or rooting out addictions are more successful if we consciously try to embed healthier responses, and repeatedly practise doing so.

In terms of how we run systems in the real world, there are intriguing parallels. Compulsivity combined with an unexamined preference for complexity can lead to a group mindset of ‘business as usual’ where an outdated attachment to persevering keeps us stuck. Terence Mauri is the founder of the management think tank Hack Future Lab and author of *The Upside of Disruption: The Path to Leading and Thriving in the Unknown*. He strongly believes that we have made constant learning too strong a focus, both in business and in life, and that this model requires an upgrade for our present times. ‘Unlearning could be the highest form of learning<sup>38</sup> in a post-AI world,’ he writes in his book. ‘It’s the ultimate insurance policy against Zombie Leadership (dead leadership that fails to adapt to changing circumstances) and “enshittification” – a term coined by academic Cory Doctorow to describe the slow decay in everything we do ... Unlearning helps us move from reactive to proactive resilience; update assumptions and behaviors to make space for new learning and keep pace with change. We can’t put more into a full cup.’

Unlearning bad habits and eliminating out-of-date ideas sounds like a no-brainer if we want to remain fit, physically and cognitively, but how should we go about emptying our cup from time to time? Rest, meditation and critical thinking will all help. As we are seeing repeatedly, wellness and intelligence are both threatened by the same environmental factors (stress, poor diet, lack of access to clean air and green space), so reducing exposure to the negatives and boosting the positives is always worthwhile.

But how to figure out what’s harmful or out of date and what’s still useful, when to persevere and when to pivot, will always require mental effort. Instigating a response, whether that’s to eliminate a particular behaviour, or to modify or build on it, will take more cognitive effort. Effective long-term thinking is a precarious balancing act of ensuring we persevere in the right direction rather than continue to build blindly on past mistakes. It’s hard but necessary and valuable. As Stephen Hawking famously observed: ‘Intelligence is the ability to adapt to change.’ That’s as true as it ever was.

# Risk assessment, curiosity and reward: another delicate balancing act

How many times today have you had to figure out whether a hypothetical event in the future might be a risk to your health or happiness? For example, deciding whether to take the kitchen stool out into the garden so that you can stand on it to reach the tops of the bushes that need pruning back. Or applying on a whim to a job in a different city where you know nobody. How many times have you wondered whether taking a chance on something (that stool, new job in a different city) might be worth a shot? The delicate balancing act of assessing risk and reward is very much part of everyday life, even if you don't go in for skydiving or own a motorbike.

Human beings have been weighing up uncertain risks versus potentially significant gains ever since our ancestors were foraging, hunting or choosing that night's resting place. It's one of the skills that has most obviously underpinned our species' survival. This explains why, although we're all on a spectrum of propensity for risk, most people cluster closer to the risk-averse end of the scale. Thanks to our innate negativity bias we tend, in general, to see dangers and problems rather than invitations and opportunities, because survival for any individual has always depended on not taking unnecessary risks.

Negativity bias operates at every cognitive level, from basic perception to sophisticated conscious thought processes, including risk assessment. It's powerful but not immovable, and while it can be a check on our creativity and curiosity, it's not the enemy. By being mindful it is possible to adjust negativity bias, but it's been around for a long time so it's worth factoring it in when thinking about your own and others' ability to assess risks effectively, especially when the landscape we're operating in is changing fast. Such uncertainty will push our evolved risk-aversion to the fore. While pausing is always valuable, being too risk-averse is not. Sometimes, we might benefit from leaning into risk or at least bringing more conscious thought to this often unconscious process. Ideally, we would analyse our initial reactions, pause and consider fully, then weigh up the potential risks and rewards before determining what action we should take.

The essential neurology of risk assessment<sup>39</sup> is relatively straightforward. As well as the prefrontal cortex, deeper, more primitive

circuits are involved, including the motivational and reward-seeking striatum, which is buried deep in the centre of our brain, and the insula cortex. Present in both brain hemispheres, the latter region is involved in a wide range of processes, from self-awareness and intuition to regulation of the sympathetic and parasympathetic bodily responses (respectively the network of nerves regulating the fight or flight response when stressed, or relaxing your body once the danger has passed). When weighing up options, the ventral striatum and anterior insula are both activated. If the former is more highly activated than the inhibiting anterior insula, then the risky but potentially rewarding choice will win out. If the anterior insula has the upper hand, a safer choice will prevail. The executive functioning of the prefrontal cortex also helps to modulate the influence of the other regions involved in this risk-versus-safety matrix.

We may have a general, species-level preference to stay safe most of the time, but there is of course a lot of variation between individuals. Fondness for high-risk, high-reward choices is an eye-catching trait. You may well have a sense of how it applies to you or the people you love or work with. Do you (or they) prefer to play safe, or do you (or they) have an appetite for risk? Maybe you're comfortable with ambiguity if you know there could be a pay-off; or maybe you find ambiguity deeply uncomfortable. Unsurprisingly, scientists have also noticed this behaviour and wondered if they can measure it. Propensity for risk turns out to be highly measurable.

Mengmeng Wang and colleagues at Shanghai<sup>40</sup> International Studies University published an illuminating assessment in 2022. They pooled the results from twenty-two studies that used the Balloon Analogue Risk Task,<sup>41</sup> which was developed in 2002 and is now a widely used paradigm for assessing risk-taking propensity. In the Balloon Task, participants sit at a computer screen on which they're asked to click a button to inflate a series of balloons, with each click blowing up a balloon and adding more money to a virtual pot in the process. The object is to build the biggest pot within the time limit. Each click will either inflate the balloon, adding to the pot, or cause it to pop, losing all the accrued money and ending this round of the test. Sometimes a balloon can be inflated seven, eight or even nine times, while at other times it may burst at the second click, and there is no way to predict the outcome. The average number of clicks over the task provides an objective assessment of a participant's risk-taking propensity. The higher the number of clicks, the more comfortable that person is with risk-taking.

When Mengmeng and colleagues analysed the data according to the age group of the participants, they found that adults were far more risk-averse than adolescents and built up correspondingly smaller pots of money. This was not surprising given what we know about novelty-seeking and reward and risk assessment in the adolescent brain. The interesting thing was just how hard adolescents' brains were working across all three key brain regions involved, compared with adults. They may have been more open to risk and attracted by reward, but their decisions were clearly better informed than the adults', their brains showing greater activation in the insula, striatum and prefrontal regions. They might have felt the strong lure of the striatum-based reward circuits, but the insula cortex must also have been involved, as reflected in an intuitive response to environmental cues, including social signals about what other participants were doing. (Teenagers are known to be highly sensitive to social pressure.) Their decision-making prefrontal cortex, meanwhile, must also have been working on overdrive as they tried to weigh up the risks and rewards and balance everything out. The teens aced the Balloon Task, seemingly not because they were blindly chasing rewards with no care for the risks, but because they were more open to the range of information available to them.

Mengmeng's analysis highlighted that, in both adults and adolescents, the anterior cingulate cortex also got involved. Present in humans and other great apes, this highly specialized region of the brain contains a high density of spindle-shaped neurons that are thought to play a key role in emotions and empathy, whether for one's future self or for others. Considering how decisions are going to make us and others feel seems to be an important factor for adults and teens alike. We use our imagination and our emotional intelligence to evaluate how any decision we make now is likely to affect how we feel in the future.

Deciding whether to make a risky choice or play it safe is always a balancing act between brain circuits. It will play out differently depending on a person's age and the environmental or social context, not to mention the perceived value of the rewards. One of the most fundamental and universal rewards is that of discovery, or satisfying our curiosity. Curiosity also famously killed the cat. 'What happens if I do this?' thinks the baby who's about to push their fingers into the plug socket. Usually the risk-to-reward ratio is not so extreme. 'What's on the other side of that hill?' or 'Shall we try a Malaysian takeaway for a change?' would be more typical.

In every case, reliable assessment depends on being able to imagine the potential rewards and risks in the first place, which is why the baby is at a disadvantage – they lack the information that experience brings, though we have to hope a hypothetical carer is about to swoop down, remove them from danger and teach them about consequences. (We're back in the realm of the imagined situations again; creativity's core skills truly are foundational.)

Curiosity may be a virtually universal experience but, as ever, some of us feel its attraction and rewards more strongly than others. Those who have been diagnosed with ADHD, for example, are highly curious as well as prone to risky behaviours. The relative volume of brain regions in such individuals offers a fascinating glimpse into the delicate balancing act that's going on when we're weighing risks. First up is the hippocampus, part of the default network involved in creativity and in memory. In people with ADHD the hippocampus is enlarged,<sup>[42](#)</sup> which seems to be at the expense of two other regions – the amygdala, or fear centre, whose volume is typically decreased, and the right and middle prefrontal cortex,<sup>[43](#)</sup> whose activation is decreased. ADHD is linked to greater imaginative skills<sup>[44](#)</sup> (larger hippocampus) but also risky behaviours (smaller amygdala) and greater impulsivity (dampened prefrontal cortex activity). No wonder people with this condition (and other individuals without a diagnosis but with similar profiles) are often highly motivated by the buzz of discovery and are less concerned about any risks they might run in the process.

It's been suggested that this ADHD-typical brain profile might have evolved at some point in our nomadic history when communities had to forage and hunt for food. Individuals with this sort of brain could imagine a future of greater reward and were prepared to personally risk getting there for the sake of the group. This idea is supported by research into the brain profiles of people who still live a nomadic lifestyle in some regions of Africa,<sup>[45](#)</sup> where there is a higher than average number of individuals with genetic variations also implicated in ADHD.

In 2024 the hypothesis was tested in a virtual-reality setting<sup>[46](#)</sup> in an experiment conducted by Michael Platt, Professor of Psychology at Pennsylvania University, in which 457 participants were asked to pick as many berries as they could within a limited time from virtual bushes on a computer screen. After a while the participants inevitably had a choice to

make: either stay at the same patch of rapidly depleting fruit bushes, or spend time travelling to a new area. In some cases, travelling to a new bush on the screen took just one second. In other cases it took five, and it wasn't predictable how long the 'journey' would take.

The researchers discovered that those with ADHD-like traits were more likely to leave a patch sooner, explore further afield in search of a bush offering greater reward, and risk the time it took to travel, rather than staying in the same spot. These people had collected significantly more berries than all other groups by the end of the experiment.

Imagination and curiosity are great at motivating us to get started on a daunting task and to keep looking for solutions even as the search becomes more challenging. But when we move out of a virtual-reality simulation into the real world, a propensity for curiosity-driven, highly risk-taking behaviour can be perilous if it outweighs an ability to perceive risk. After all, we wouldn't have much long-term future to plan for if we did something so risky that it finished us off. Being able to assess risks has evolved to offer a necessary counterpart to our novelty-seeking curiosity.

If the balancing act has always been delicate, the environment we find ourselves in now (saturated with information, awash with dopamine-driven, thrill-seeking loops and with the speed of change accelerating all the time) is making it harder for all of us. How best to flex our imaginative powers and deploy our drive to explore, without sacrificing appropriate analysis of risk? How can we resist impulsivity and its cousin compulsivity while still reaping the benefits of persisting with our goals? How, in short, can we think and plan and execute projects over longer timeframes to secure the successes we want, when our world seems intent on making that ever harder?

Among the many worthwhile suggestions one might make about controlling exposure to the dopamine hits and stress triggers of social media, scrolling-news sites or fast food, I'm convinced that diet has a major part to play in maximizing our cognitive fitness for the future we seem to be hurtling towards. There is a whole chapter on that coming up.

Meanwhile, confining myself to measurable impacts on brain regions involved in the long-term thinking skills we've been looking at here, I would say that physical exercise is the single biggest intervention you can make. It has been shown to increase the rate of neurogenesis (the birth of new neurons)<sup>47</sup> in the hippocampus, which, as we've seen, is involved in



both memory and imagination. Outdoor exercise in particular seems to have huge benefits<sup>48</sup> not only for physical and mental health, but also for boosting creativity. An hour-long walk in nature reduces amygdala activity<sup>49</sup> (although, intriguingly, this study found the result significant only for women, not men), making it easier for the risk–reward matrix to do its work rather than being overruled by the fight-or-flight mechanism. In short, getting out into green space for regular exercise is great for your body and mind in the here and now, but it also shores up your capacity to plan ahead and think effectively about the future.

## Stress: a ticking time bomb for our brain

A short spike of stress can be highly motivating, as anyone who's ever chased a deadline knows. It can make us alert, focused and mentally agile. Prolonged stress, on the other hand, is a grievous threat to our capacity to think intelligently, especially about the longer term. It undermines everything our brain is trying to do when it's delaying gratification, pausing, reflecting, evaluating risks and rewards, learning or unlearning, or weighing up whether to persist or pivot. Once our brain has become chronically stressed, all those activities are virtually impossible. We're left grappling with the damaging impact of cortisol, as it strips away neural connections, reduces plasticity and flexibility in thinking, and in chronic cases, causes brain-cell death. Unfortunately, stress and anxiety have become the medium in which many of us swim.

I'd like to begin this section with a backward glance at a previous moment in history when technology was making such extraordinary advances that the whole fabric of society, and our context as decision-making agents, would be altered. It was a time of acute and prolonged fear for millions of people across the world. History is not my field, but some of the parallels with the moment we find ourselves in now intrigue me greatly.

Robert Oppenheimer, the great theoretical physicist<sup>50</sup> and Professor of Physics at the University of California, Berkeley, explored the big questions of the universe using quantum mechanics to understand the precise nature of reality. Recruited in 1942 to work on the Manhattan Project, he became leader of this enterprise to create the world's first nuclear weapon. After its deployment on the Japanese cities of Hiroshima and Nagasaki in 1945,



which killed hundreds of thousands of people, he became vocal in calling for international collaboration to regulate the nuclear technology he had co-created.

Oppenheimer was neither careless nor blinkered when he was working on the Manhattan Project. On the contrary, he was dedicated, conscientious and thoughtful. I find it incredible that he and his colleagues working in the New Mexico desert were able to plan and execute their project over such short timeframes and under such pressure. The creativity, capacity to pivot, learn and unlearn and persevere that these scientists displayed was nothing short of exceptional.

But their capacity to think long-term was also compromised by the context of fear in which they were working. The world was at war, their country and allies were under attack and they had been charged by political leaders with a moral mission to help save them. The project began under a cloud of panic that the Germans would get there first. The demands were endless, short-term and urgent, and the stress must have been overwhelming. In these conditions, no wonder Oppenheimer was unable to fully appreciate the long-term, real-world implications of what they were doing. It's hardly surprising that the team, who were, after all, simply fulfilling their brief, were unable to think six steps ahead and in the round, asking complex political and philosophical questions about value and risk, trade-offs and red lines.

The question of whether the deployment of the bombs was justified is beyond my scope here. I'm interested in the way Oppenheimer reacted afterwards. I'm not the first person to note that an unprecedented technological leap, with the potential to be highly beneficial to humanity or devastatingly destructive, is by its nature difficult to contain, plan for and steer into the future. Arguably, he was that first person; and his message was a plea for everyone to pause, slow down, step away from the fear-based thinking that had dominated the Manhattan Project, to reflect and collaborate on intelligent ways to avert a continuation of this arms race.

Thankfully, very few of us are living with the levels of fear and stress that I've just described, but we are living through a technological revolution triggered by artificial intelligence, which has unleashed both huge excitement and great anxiety. Even before that, our everyday environment had become saturated in the sort of stressors that combine to create permanent low-level anxiety for many, as we saw in [Chapter 1](#), on

emotions. A drip feed of smaller worries ends up undermining our well-being and our ability to think clearly, with a significant impact on the health of our brain.

When we sense a threat, ingrained biological responses that evolved to protect us kick in to alter our behaviour, preparing us to either fight or take flight. Our body releases adrenaline and cortisol, making us feel more alert, so that we can act faster; the plasticity in our brain increases, so that we can think more quickly. The amygdala lights up with electrical activity to help direct these responses, but it occurs at the expense of the anterior cingulate cortex (ACC), which is involved in monitoring uncertainty and conflicts, horizon-scanning and forming novel partnerships and collaborations with other people. Fear essentially primes our brain to prioritize short-term survival over longer-term collaborative problem-solving. It becomes difficult to see past the immediate danger and consider what might be the most intelligent, strategic view. We might find ourselves in a damaging metaphorical arms race.

All of this is one of the most universal (because most ancient) human cognitive behaviours, but when we peer into the brain to try to understand how different people react under stress and how resilient they might be in their response, we obtain intriguing results. It is known, for example, that different individuals exhibit different fear responses. The sensitivity of different regions in any individual brain is massively shaped by the genetics that lay out the unique neural circuit board. If your amygdala region is predisposed to be active, for example, you will be more reactive to uncertainty or potential threat, and your fear response is likely to be greater. If your amygdala is less sensitive, your responses are more likely to be influenced by activity in the ACC and your fear response will be buffered by focusing on problem-solving and collaboration.

These innate neurological features have been linked to real-world behaviours in fascinating ways. A study conducted in 2011 by Professor Geraint Rees<sup>51</sup> and colleagues at University College London set out to look at neurological differences between people with different political views. They found that participants who described themselves as having liberal attitudes tended to have a larger ACC, whereas people who described themselves as conservative had a larger right amygdala. The team stressed that this was an observable correlation rather than a causation, but they speculated that having a sensitive amygdala might drive a person towards

an anxious and self-protective raft of views, whereas an active ACC could allow for a less emotional and reactive set of attitudes to form. ‘It is conceivable that individuals with a larger ACC<sup>52</sup> have a higher capacity to tolerate uncertainty and conflicts, allowing them to accept more liberal views,’ the study concludes.

Whatever our individual biology or ideology, none of us is immune to the negative impacts of stress and fear on our capacity to think long-term. If we find ourselves in a metaphorical arms race, perhaps it is wise to be armed, but it’s imperative that we strengthen our capacity to resist the knee-jerk urge to pull the trigger. Reducing our stress levels and learning techniques for switching out of fear-based thinking is crucial. Breathwork has been proven to be highly effective at switching off the parasympathetic nervous system and allowing a return to the resting state of our sympathetic nervous system. A simple technique such as box breathing (breathing in for four counts, holding your breath for four, breathing out for four and holding your breath again for four, before repeating the cycle) is easy to learn and to implement at any moment, along with other techniques derived from yoga, meditation or mindfulness, all of which can also be useful. Find your preferred activity, get out into your local park, take exercise, listen to music – do whatever helps alleviate your anxiety and stress, because if your brain is awash with cortisol, the corrosive effect on your mood, mindset and intelligence is very real.

Once you’re feeling calmer and less reactive, you might wonder what else neuroscience can offer to help you think strategically over the long term and be successful. It’s time to consider the potential impact of long-term thinking conducted in a group. Let’s return to Qarrrsiluni, or rather the prosocial collaborative and collective wisdom that it both fosters and generates.

## Prosocial thinking: the basis for long-term thinking in groups

There are limits to how far you can think ahead if it’s just you, on your own, wrestling with all the immediate demands on your attention. Planning and executing complex projects that will extend over a significant time period is hard work. As we’ve seen, the sophisticated cognitive activities

that underpin them involve multiple brain systems working in tandem, and in tension with powerful impulses to scratch a dopamine itch. There's only so much of this cognitively demanding work any individual can do. But when we team up with others, we spread the load, play to our individual strengths and start to feel more confident that our long-term security and well-being will be protected. We feel safe enough to start thinking big.

As we saw just now when looking at stress, a feeling of safety is fundamental for smart thinking about far-off plans; all animals, including humans, feel safer in a group of their own kind. To be left behind (or, even worse, to be an outcast) makes any individual animal supremely vulnerable, which is why one sees examples of prosocial bonding behaviour everywhere in the animal kingdom. We all need allies, friends, someone who might share their food with us when we're struggling.

It's fascinating to see how many prosocial behaviours seem to be future-focused, from the relatively simple, such as squirreling away enough food for a whole family over the winter, for example, to the passing on of learned behaviours to the wider community. The former may be driven by a survival instinct, but it's no small thing since it requires the ability to delay gratification as well as excellent memory skills. Corvids such as crows and ravens<sup>53</sup> demonstrate how social learning is handed down the generations when they share their innovative techniques for tool use. Their descendants and the wider community all benefit. Dolphins remember each other's characteristic whistle,<sup>54</sup> as one study has shown, even when they haven't seen each other for forty-three years. This requires setting aside considerable cognitive resources, but it's evidently worthwhile for dolphins to remember allies and partners over long stretches of time. Many species build these wider and long-lasting social ties through altruistic acts as a means of 'insurance', setting up expectations of mutual aid in a hypothetical time of future need that instils a feeling of safety in the here and now. Humans are no different. It comes back to the old proverb that what goes around comes around. When we act altruistically, we are (to put it in a transactional manner) banking potential social credit to draw on in difficult times ahead.

Altruism may be a self-serving instinct in some ways, but it is not always reducible to a transactional exchange. Plenty of animals offer support even when it goes against their own immediate interest, and to a wider group than their own offspring. Altruistic acts have even been observed between

different species, such as African grey parrots voluntarily helping other birds<sup>55</sup> to receive food rewards, vampire bats regurgitating their food<sup>56</sup> to help starving roost-mates, or a female gorilla named Binti Jua<sup>57</sup> rescuing a three-year-old boy who had fallen into a gorilla enclosure and cradling him until help arrived. Such acts imply something akin to empathy. Their practical result is to shore up a group identity through shared values and mutual reliance, boosting the group's resilience and capacity to carry out necessary tasks, from hunting to infant care. The more effective this prosocial behaviour, the more capacity a group has to perform ambitious and long-term activities. Thinking more broadly – about other individuals in your community – enables you all to think longer-term.

The benefits of prosocial behaviour to a group's effectiveness are of course replicated in humans, in countless ways. A shared sense of values, purpose and identity provide the foundations for projects from fundraising for a new local adventure playground to conducting scientific research in a desert in a time of war. We need each other when we're planning and executing larger-scale and longer-term projects, and we can only operate together intelligently if we have a certain base level of capacity to think broadly – about each other's needs and perspectives – as well as long-term.

Neuroscientists have become more interested in the study of empathy and altruism over the past decade or so. In 2022, a team of researchers based at Birmingham and Oxford<sup>58</sup> universities and led by Dr Patricia Lockwood reported they had pinpointed the neural circuit underpinning altruism, in a small but highly significant study. The team took thirty-eight participants aged between eighteen and thirty-five and asked them to complete a questionnaire designed to assess their empathy levels. Participants then had to carry out a series of tasks while lying in an fMRI scanner so the scientists could observe which brain regions were activated during each stage of the task. They were invited to 'work', in order to help either themselves or an anonymous stranger, or to 'rest'. If they chose the work option, they squeezed a device that measured their grip strength. They had to grip for long enough to reach a certain threshold, which triggered a reward in the form of points to be converted into money, a process they could see in real time on a screen. Before making a decision they were told whether they would be working for themselves or for another person. They then opted either to work or to rest.

The researchers found that the ACC, located towards the front of the brain, was the only area that showed the effort pattern when participants decided to help someone else. This region was not activated when they decided to put in effort to reward themselves, or when they opted not to help another person and just rest. The ACC was most active in those individuals who had indicated on the questionnaire that they were very high in empathy and who squeezed the measuring device harder to help others out.

This finding about ACC brain activity is, at first glance, a surprise. This brain region has previously been associated with horizon-scanning for signs of important developments, as well as seeking out new partnerships with other people that might help us to adapt and innovate. In other words, it's strongly associated with long-term thinking but had never previously been associated with empathy or generosity. And yet, new relationships always depend on someone making an initial move to open up the space for communication. Trust is required to take the potentially risky step of collaborating with someone you don't know. What better way to create that trust than to bestow an unexpected gift in an unforced gesture of altruism? The benefits for expanding a group's collective brain power and experience are clear.

Being able to think beyond our own preferences and see things from another person's point of view is a foundational skill that underpins successful social interactions and relationships of all kinds, but like so many of the complex skills required for long-term flourishing, it isn't acquired overnight. It takes years for the skill to develop throughout childhood and adolescence, from emerging theory of mind, as a child begins to grasp that other people are separate and have their own views and preferences, to empathy and eventually sophisticated abstract thought about why and how people think and behave differently from oneself.

This capacity to think beyond our own lived experience, the demands of the present moment and immediate cause and effect, has been referred to as 'transcendent thinking'. It seems to represent a crucial stage in a person's cognitive development when they gain the ability to analyse and interpret events in a deeper way that goes beyond immediate concerns.

In 2024, Professor Mary Helen Immordino-Yang<sup>59</sup> and colleagues at the University of Southern California in Los Angeles published the results of their groundbreaking study on how teenagers develop this capacity to think



both deeply and laterally. They started collecting data around 2012 and, over a period of five years, they followed sixty-five 14–18-year-olds whom they had recruited from public high schools in Los Angeles. Participants were shown a series of short documentary films about teenagers from around the world, some of whom had faced complex social or moral challenges. (The Pakistani education activist and Nobel Prize laureate Malala Yousafzai, not yet famous, was among those portrayed.) The team interviewed the Los Angeles teenagers, asking them the open-ended question: ‘How does this person’s story make you feel?’ After the interview and two years later, each teenager was given various types of brain scan, and the researchers followed up with online questionnaires and phone interviews over the next five years.

Unsurprisingly, there was considerable variation in how the participants grappled with the social, political, personal and ethical questions raised by the documentary stories. All the teenagers considered aspects of context or the bigger picture, and/or compared their own situation and that of their friends with the teenagers they’d just seen on film. Some of them did this to a greater extent than others, however, pursuing lines of thinking to highly abstract conclusions about hypothetical alternatives and comparisons.

Over the two-year period between the scans, the brains of those young people who were more comfortable with what the team called ‘transcendent thinking’ showed marked increases in coordination between two key brain networks: the default-mode network, involved in reflective, autobiographical and free-form thinking as well as creativity, and the executive control network, involved in effortful and focused thinking. When the team followed up with participants five years after the initial interview, the more an individual had engaged in transcendent thinking during the initial interview, the higher they reported their life satisfaction to be as young adults, and the more satisfied they were with their close relationships. The team also discovered that increased integration between these two brain networks could predict the development of a coherent sense of identity by the age of nineteen, which in turn forecasted their degree of self-liking and relationship satisfaction in close relationships in young adulthood – evidence of a neurodevelopmental cascade linking social understanding to future brain maturation and well-being. In essence, the ability to envisage hypothetical events and put yourself in another person’s shoes helped to build self-confidence, leading to greater happiness down the



line. These findings were independent of IQ, ethnicity and gender, and socioeconomic background.

Immordino-Yang champions a view of the adolescent brain as possessing extraordinary gifts of creativity, empathy and innovation rather than the more traditional perception of it as being a deficient adult brain that hasn't yet learned how to regulate emotions or assess risk. Her experience of teaching teenagers had shown her that when their passionate curiosity, idealism and emotional openness was encouraged, it could translate into high levels of engagement at school and flourishing social skills. The findings of her study underline the importance of inviting teenagers to look at things from a different perspective and wider viewpoint from a young age, rather than shielding them from the complexity of the world. Her conclusion was that 'civic-minded educational approaches'<sup>60</sup> are likely to have a highly positive effect on attainment, mental health and long-term happiness. Above all, she stressed 'the important role teens play in their own brain development through the meaning they make of the social world'.

I love this study's results for the light they shine on the exquisite dovetailing between individual and group intelligence, the relationship between empathy and self-actualization, a smart brain and a contented one. Prosocial and abstract thinking helped these teens to literally bulk up whole brain regions, figure out their values and identities and arrive at early adulthood ready and willing to work alongside others.

We know that collective intelligence can flourish only when there are plenty of different viewpoints to draw upon and when the culture of the group fosters respectful listening and courteous debate. Without a wide range of perspectives you end up with group think, but without a culture that ensures each person is heard, you end up either with a cacophony of competing voices or with a dictator and their compliant minions. That's why empathy, emotional intelligence, perspective-taking, active listening and all the other skills required for collective intelligence are such crucial elements of long-term thinking on a large scale. Without these prosocial abilities a group can't operate intelligently, which will limit the size of the projects that can be successfully completed.

That's a conclusion I find worrying on some days but which fills me with optimism on others. Long-term thinking at the scale we require to tackle big problems such as the energy transition or planning for the next pandemic

depends on cognitive skills that are innate but cognitively demanding. As we've seen throughout this chapter, long-term thinking is a complex, whole-brain activity that takes place in tension with its short-term counterpart. We typically don't even begin to get good at it until adolescence and it can be easily derailed by environmental factors such as social pressure, isolation and stress. But when I read about new studies into the neural basis for thinking about others and the future, beyond ourselves and immediate groups, I grow more hopeful. Human beings are good at this sort of thing, as our amazing cultural and scientific achievements attest.

## Scenius – creating group environments that help our brains to thrive

Long-term thinking benefits from support by others, including allies and mentors. Long-term projects benefit from a group to carry them out. And groups need a supportive environment so they can come together and do their best work. I've been very lucky to have lived and worked in several such places and consequently I'm a huge believer in the value of creating and fostering them through culture and the built environment.

My work life is based at Magdalene College, Cambridge, a site of continuous academic study for nearly six hundred years since it was founded in 1428 as a Benedictine hostel. One of the smaller Cambridge colleges, it provides a stunning base for around 400 undergraduates, 200 graduate students and 100 Fellows. Magdalene is located in the centre of the city beside the river Cam, and when you step in from the hustle and bustle of the main streets, passing through the heavy medieval wooden gates to the quiet courts and cloisters of the college, it's impossible not to be struck by the sense of history and accumulated knowledge and wisdom.

If you dine in college (it's one of the last colleges in Cambridge in which you can do this almost every night, by candlelight in the formal hall), you appreciate that this ritual, which hasn't changed much since 1428, brings the student and Fellowship community together to eat, converse and socialize, fostering multidisciplinary learning, creating support and a sense of community. It also promotes an understanding that everyone here is not merely an individual with an ego but also part of something larger. For me,

at least, I feel we are all in the business of passing the baton of open-minded wisdom down the generations, from one person to the next.

In one corner of the Fellows' Garden, set back from the river, is the New Library. When it won the 2022 Royal Institute of British Architects Stirling Prize, judges commended it as 'a light-filled, warm-wood interior that lifts spirits and fosters connections'<sup>61</sup>. Designed to last at least four hundred years (by contrast with most new buildings in the UK, generally built to last no more than a pitiful sixty), it was created to fulfil a specific need. It's a place for students to learn together: either to study quietly on their own but without feeling isolated, or to work as a group. The construction of the library was requested by the students themselves. They wanted a new place where they could help each other stay motivated by seeing that they were not merely pursuing their own studies but were part of a community. It's too early to say if the New Library will have a measurable impact over time on student well-being and academic scores, but it is already very much appreciated. Indeed, it's so popular that, at the students' request, the porters now perform occasional security checks to remove those students from other colleges who have been sneaking in behind Magdalene students, through the entrance doors accessed by security card, in order to surreptitiously study there.

About one hundred metres downstream from the New Library is the start of the river Cam houseboat community, with around seventy residential moorings. I lived afloat here for a decade as I completed the final stages of my doctoral studies and started working at the university. That houseboat community has spawned notable success stories, acting almost as an incubator hub. Not only did it produce several award-winning authors, broadcasters and artists, but also four very successful business people who, at a relatively young age, kick-started four very different, multimillion-pound businesses that are still thriving. These businesses each have longevity, sustainability and ethical education at their core. There's an international swimming school, a billion-dollar-turnover solar-panel company, and Zedify, which offers cycling training for children. The outlier here is the award-winning Jack's Gelato, whose ice cream is made by hand using locally sourced ingredients but may or may not have a wider social purpose. (Unless you count motivating undergraduates to keep plugging away at their studies through the sheer deliciousness of their ice-cream rewards.)

Reflecting on my life in these two relatively small but vibrant communities, each very different and yet both supportive and successful, made me wonder what makes a space buzz with ideas and the impetus for seeing projects through to fruition. The term ‘scenius’ was invented by the pioneering musician and record producer Brian Eno to refer to the collective intelligence or communal genius that emerges from a group, a place or a ‘scene’. It has most often been applied to groups of artists, musicians and creatives such as the Bloomsbury Group in Edwardian London or the Manhattan art scene in the 1960s and 1970s. There have of course always been gatherings of thinkers and creators. Arguably Renaissance Florence was an example of scenius before the term was coined.

But scenius doesn’t have to belong exclusively to artists, or to take place in gritty urban centres. In fact, applying neuroscientific principles to creating environments that will support it suggests that calm and green space might be just as effective, if not more so. We know that access to nature promotes alpha-wave activity in the brain,<sup>62</sup> which is associated with creativity, innovation and problem-solving. It has also been shown to boost resilience to the negative impacts of stress<sup>63</sup> and foster a greater sense of connection with both our human community<sup>64</sup> and nature as a whole.<sup>65</sup> It has even been shown to improve attention<sup>66</sup> and boost IQ scores, the gold standard for measuring intelligence.

In 2022, a study of almost 4,000 primary-school-aged children<sup>67</sup> in Portugal demonstrated that those with access to green space did better cognitively overall, and had a higher IQ. Researchers found that part of the benefit was attributable to physical exercise, which makes sense given that it promotes neurogenesis, as we saw earlier in the chapter. They also concluded that a reduction in exposure to air pollution was a factor, as a previous study of over 2,500 Spanish schoolchildren<sup>68</sup> had suggested. But these factors were insufficient to account for the whole effect, which was huge. The team realized that regularly being in green space was the largest contributing environmental factor to the children’s IQ besides access to education. Other than going to school, being outside in nature was the single most effective and important thing for their attainment and brain health. This finding has been corroborated and observed in adults as well.

In 2024, a study of over eight hundred adults working or studying<sup>69</sup> in different states of the USA discovered that individuals who work and live in areas with greater access to nature spend more time outside and enjoy that time to a greater degree. These experiences are in turn associated with greater engagement and creativity at work.

Green space seems to support creative thought, resilience to stress and feelings of social connection: the ideal ingredients for boosting long-term thinking at scale via scenius. The evidence from my own life stacks up: both my Cambridge communities are close to green space. Magdalene is on the banks of the river and the New Library has vast windows that overlook the Fellows' Garden, where the students walk, rest and play. The houseboats, meanwhile, are nestled downstream, moored alongside the vast public parks. Both the college and the houseboats also provide space and time for quiet reflection and meditation, and plenty of exposure to natural light. Then there's the fact that natural materials are known to have a calming effect on the mind. Houseboats are largely lined with wood and the new college library was built with exposed timber. Biophilic design draws on research that shows how environments rich in natural materials like exposed wood are associated with a drop in cortisol,<sup>70</sup> lower blood pressure<sup>71</sup> and improved focus, concentration and cognitive performance.<sup>72</sup> The perfect setting, in short, for more creative, resilient and intelligent thinking.

Beyond the built and green spaces, there's the matter of the people who occupy them, and how they interact. There is a strong heart in scenius, not just the head. As we discovered in [Chapter 1](#), the pandemic showed us how much we need each other: company improves our physical health, lifts mental fog, even increases our IQ scores. When new ideas can hop from mind to mind, they create an avalanche of innovation. Working together as a group allows us to iron out any bias or errors in our own individual information-processing, and to synchronize the way we stitch information together. This brain synchronicity helps to create a sort of 'super-brain', so that we literally see the world in the same timeframe – and much more accurately. It becomes far easier and more effective to work in collaboration. We have greater brain power to access and it's easier to build consensus, with innovation, learning and memory all benefiting in the process.

The benefits of a conducive environment and a supportive community if you're trying to make something innovative, ambitious or experimental have always been felt by thinkers and creators. That's why scholars banded together in universities, artists hung out in Paris and New York, and tech entrepreneurs rented garages in Silicon Valley. During the COVID pandemic, Magdalene students were separated from each other by isolation measures. Many of them were sent home, where they started to study with Zoom switched on, to create a digital version of the college library. Individuals were working on different projects but felt better knowing that there were others out there doing the same, comforted simply by being able to hear them breathing. They could sense that, during this period of viral threat, they needed each other, for both their mental and physical well-being. Living off-grid on a houseboat likewise fostered great community spirit. It was impossible *not* to get to know your neighbour and feel part of a tribe. When somebody's engine broke down or their chemical loo packed up, we all rallied round with offers of help and spare parts.

The spaces and buildings we inhabit can, by their design, help create a culture of curious, reflective, non-combative thinking in which different perspectives are welcome. Whether it's acquiring more houseplants or enjoying shared lunch breaks with the team in the park, tweaks to our individual environment and routines can boost smart thinking and mental health. According to a 2024 study, having houseplants around us<sup>73</sup> brings about profound psychological and physiological relaxation, including a reduction in negative emotions and an increase in positive ones, a lower heart rate, a reduction in sweating, inflammation and cortisol production, and enhanced alpha brain waves. Merely being able to see and smell plants around you has a calming effect on the nervous system. When we're able to think effectively in groups, we're setting ourselves up for a flourishing future. The effects can ripple far and wide, even across the generations.

## Legacy – how can we help our descendants thrive?

Humans might be unique in their propensity to consider their legacy in such highly abstract terms. Every species wants to breed and for its offspring to be successful and, as we've seen, numerous species display generation-

spanning long-term thinking. But as far as we know, humans are unusually invested in what's been called 'cathedral' or 'seven-generation' thinking. Cathedral thinking is the capacity to imagine and work on something that you will never see completed, to play your small part in a larger whole on a project that might not be finished for another fifty, one hundred or even three hundred years. While in effect synonymous, seven-generation thinking is, to my mind, less outcome focused, more about expanding that circle of care. It asks us to take into account the needs of not only our own descendants, but to think of those outside our genetic lineage, while also looking generations into the future, as we make decisions today.

Whether we prefer one term or the other, this most complex and epic form of thought draws upon the divergent and convergent creativity that can throw a dozen ideas into the air and then chase one down to bring it to fruition. It depends completely on delaying gratification, reflecting on means as well as ends and combining persistence and mental agility. It requires us to cultivate empathy and broaden our thinking to take in a wider perspective. This is transcendent thinking writ large across space and time, and human beings have always been brilliant at it. These days, thanks to all the impediments we've been looking at, our capacities are being eroded even while the need has arguably never been greater.

What helps us to lean into cathedral thinking? Everything we've discussed so far in this chapter will help us to think in timescales that extend beyond our own death, far into a hypothetical future. And here I see inspirational ideas from cutting-edge science and indigenous wisdom alike.

When we think about what kind of legacy we might want to bequeath our biological descendants (if we have them) and our community more generally, it might help to know that the products of our long-term thinking can be passed on not just in the form of a library or a scientific breakthrough but also in the infrastructure and influence of our own mind. You might never win a Nobel Prize (let's face it, probably none of us will) but your mind is nevertheless capable of shaping the world view of people as yet unborn.

Scientists working in the field of epigenetics have shown that the ripple effects of your choices and behaviours mould those of your descendants in very concrete ways. What you think today can directly affect what your children think after your death, not because of anything you teach them but through changes to the way their genes are expressed. Biological legacy is



no longer confined to genetic inheritance via the sequence of nucleotides in the DNA handed down from your parents. It's more sophisticated and nuanced than that.

Alongside our genetic and epigenetic legacy, our interactions with others will also exercise considerable influence on people in the future. Culture influences thinking for good or ill, and every individual can play a part in creating the conditions that allow genius to emerge. Collective intelligence flows across generations, as I know from my own experience at Magdalene College. Whether we have children or not, our thinking styles, ideas and communication shape the brains and minds of others. This is what the Inuit sitting in darkness know: when our brain is healthy it is intelligent, and when a healthy, intelligent brain is thinking in sync with other minds, it receives and transmits ideas that have been circulating in the form of wisdom for generations.

If this sounds nebulous, consider the fact that epigeneticists have discovered the mechanism that allows lived experience and acquired knowledge to be passed on within one generation, by altering the structure of a particular gene. This means that an individual's life experience doesn't die with them but endures in genetic form. The impact of the starvation your Dutch grandmother suffered during the Second World War, for example, might go on to shape your mother's or father's brain, their behaviours and eventually yours. Severe deficiencies in nutrition in children<sup>74</sup> have been shown to be associated, perhaps counter-intuitively, with higher mental-health scores in their subsequent grandchildren. There is now ample evidence that trauma, phobias and fears can flow down<sup>75</sup> the generations in measurable neurological changes; but so too can resilience.

The prefix 'epi-' means 'beyond', and epigenetics thus applies to the study of all non-genetic evolutionary variation; that is, everything that is not part of the DNA script. Epigenetic mechanisms were first identified in 1925 in bacteria<sup>76</sup> and although at the time their significance was not fully understood, we can now see that a biological route has evolved within humans that invites us to consider our behaviours and choices in the very long term. Our thinking doesn't die with us; it's literally transmitted across generations.

Much of the recent epigenetic work in the neurosciences, performed in studies on organisms such as mice, has been focused on learning, long-term

fitness and the disruptive impacts of trauma on both. Professor Isabelle Mansuy and her team at the University of Zurich and the Swiss Federal Institute of Technology in Zurich specialize in this area and published a pivotal study in 2014.<sup>77</sup> The scientists carried out one of those experiments that instinctively makes me uneasy about the use of animals in research, though in this case I believe the breakthroughs and benefits are sufficiently significant to outweigh such concerns. The team wanted to know more about intergenerational effects of trauma, so they separated mice pups from their mothers at unexpected intervals and further stressed the mothers unpredictably during the periods of separation. When the mothers returned, they were agitated and subjected the pups to hectic and disorganized maternal care. The study showed that offspring grew up to exhibit behaviour reminiscent of human depression. They were also less risk-averse and had memory and social deficits.

Mansuy and her team identified changes in specific molecules known as ribonucleic acids (RNAs) – which influence genome activity including gene expression by a variety of mechanisms – in the sperm of traumatized, now adult males. When those males were bred with unstressed female mice from a control group and had pups of their own, the altered RNAs in their sperm caused behaviour in their offspring to be modified. They too were more depressed and less risk-averse than controls. It seemed that the risk-taking phenotype spread across as many as five generations. To rule out social transmission of behaviour through learning and nurture, the team injected the altered RNAs into fertilized oocytes (single-cell embryos) obtained from non-traumatized parents, and found that individuals developed from these sperm RNA-injected embryos displayed some of the same behavioural patterns as the original traumatized males. This was particularly significant because it was the first time that behaviour was inherited through injection of sperm RNA. Again, social transmission was eliminated: the traumatized males mated with females from a completely different environment and were then removed from the arena and had no contact with their offspring – but the traumatized phenotype always reappeared in subsequent generations.

A year later a similar study was published<sup>78</sup> by a group at the University of Pennsylvania, again creating a stress parameter that was induced by injection of specific microRNAs into embryos. A couple of years later and

Isabelle Mansuy and her team again demonstrated how separation trauma can result in risk-taking behaviour for up to four generations in mice.<sup>79</sup>

Wanting to see whether similar results could be observed in our species, Mansuy's team then turned their attention to the SOS Children Village Lahore, a private non-profit organization that has been working for the welfare, upbringing and education of orphans and abandoned children in Pakistan since 1977. Here, in a group of orphans aged 7–12 years,<sup>80</sup> researchers found RNA alterations in the participants' blood serum, with similar changes in the sperm of men who had been exposed to trauma in their childhood. The team then collaborated with geneticists at Cambridge University<sup>81</sup> to study how similar epigenetic changes were spread through factors circulating in the blood that had an impact on how the DNA in sperm went on to be expressed in subsequent offspring.

When Mansuy carried out a further study on mice, though, she found something interesting. The impact of early-life stress is not always 100 per cent detrimental.<sup>82</sup> Sometimes, separation of newborns from their mothers can be beneficial, at least when examined using certain paradigms. In this study, male (but not female) mice whose fathers were stressed and separated from their mothers shortly after birth (the grandpups of the original stressed mothers, in other words) showed greater behavioural flexibility and better goal-directed behaviour under stress in adulthood than male mice from a control group. For instance, they learned faster on a complex task to be rewarded with a drink of water, even if they had to wait for longer (good old delayed gratification again), and they adapted faster to changing rules governing games designed to test their speed of learning. It seemed as if mental agility and the ability to cope with a challenging situation were being passed on in the mice, and the impetus for this appeared to be early-life stress. Early-life stress in fathers had actually improved behavioural flexibility in their male offspring. What was going on?

Mansuy and her team speculated that early traumatic experiences are not necessarily and inevitably all negative. There seem to be epigenetic mechanisms that allow for them to be assessed contextually. In this case, the extreme stress in early life and the pressure pushed the male mice to adapt to challenges. The experience of trauma seems to have promoted an adaptive response which manifested itself in adulthood as an increased ability to cope with adversity.

In humans we see a similar response. Some studies show that children who have had adverse early-life experiences can follow an accelerated path of neurodevelopment. By the time they're teenagers, their neural signature is significantly more advanced than that of their same-aged peers.<sup>83</sup> They are thought to grow up early. This makes sense as an adaptive strategy and helps to account<sup>84</sup> for why individuals react in different ways to adverse events. Such accelerated neural development is related to resilience in some individuals: better mental health and well-being than in others with similar adverse experiences in early life.

That said, the full emotional cost of early-childhood trauma is generally high for a significant proportion of people.<sup>85</sup> 'It is critical that we better understand<sup>86</sup> why some young children with a history of adverse early experiences go on to develop mental illness, and others do not,' says Anne-Laura van Harmelen, Professor of Brain, Safety and Resilience at Leiden University, who is a leading expert in this area. 'This may be due to the type of experiences that they have (for instance, deprivation experiences may differentially alter neural trajectories when compared to threatening experiences), their severity, their developmental age and circumstances such as how much support they receive at school, from friends, and/or their community. There is much unknown about the effects on later life functioning, and the protective factors that may help children cope with or recover from such experiences. Unweaving these complex effects will help us better understand how we can help aid mental-health resilience in all young children.'

The picture is complex and varied, but it seems as though nature has created some very sophisticated biological mechanisms that allow the impact of certain experiences either to flow down the generations or not, depending on its value within the immediate environment. When we look at the impact of mass shared trauma on the brains of Holocaust survivors, for example, studies report that many individuals in subsequent generations demonstrated resilience and did not suffer<sup>87</sup> from a higher incidence of psychopathology, while some in fact report greater life satisfaction.<sup>88</sup> We know that resilience is highly heritable, so it makes sense that the genetic signatures that are associated with it would shift under such intense epigenetic pressure. Returning to the research mentioned earlier with a similar trend – a period of nutritional stress prior to conception resulting in

future generations reporting a greater life satisfaction and resilience – the same may be true for the skills that support the sort of intelligence that would allow a cohort to pull through in such circumstances: higher empathy, better perspective-taking and increased altruism; a greater capacity for non-reactive thinking and emotional regulation.

In all times and across all cultures, people have paid their dues to their ancestors and pondered the legacy they will leave for their descendants. Few of us believe any more that biology is destiny or that our bloodline determines who we are. And yet, the more we learn about how our body and mind work together to shape our experience, the more we can see that our life story is woven into our biology. Might this understanding increase our capacity for self-awareness and empathy? If we can grasp the potential impact of our ancestors' experiences on our own behaviour, might we be more understanding of others who are also carrying the inherited weight of experience? Would we make different choices on the basis of how they might affect our great-grandchildren?

As our knowledge about epigenetics and collective intelligence grows, our cathedral or seven-generation thinking might receive a boost. It's an idealistic way to think about legacy, but without it we will struggle to tackle complex multigenerational challenges. I hope we will do everything we can to be the ancestors our descendants need, by pushing our transcendent thinking far and wide. Conflict, neglect and trauma result in unpredictable and extensive changes. But so do trust, curiosity and compassion. Cold, lonely spaces with little potential for interaction with other people, or other species, create less engaged, less innovative minds, unable to delay gratification. Building our legacy with maximum thoughtfulness, conversely, could have effects that ripple and cascade across generations.

## Hitting the pause button

Thoughtfulness is an urgent requirement in today's world, and it begins, as we know, with a pause in which we resist immediate gratification and create space in which to calm our reactive brain in favour of reflection. This has been shown to be beneficial even at the level of individual brain cells. A molecular study published in 2019<sup>[89](#)</sup> in the journal *Nature* identified a protein almost too perfectly called RE1-Silencing Transcription factor (REST), which seems to help us live for longer. REST regulates genes in

order to suppress neural excitation. Pressing the pause button on neural activity allows brain cells to, well, rest. The researchers found human centenarians had significantly more REST in the nuclei of their brain cells than those who died in their seventies or eighties. Blocking REST or its equivalent in the animals being studied led to higher neural activity and earlier death. It seems that taking time to pause, reflect and consider rather than be constantly buzzing with activity really might be key to long-term survival. Rest makes us healthier and smarter, from individual brain cells to our whole brain connectome.

Might the same be said of our culture and society, and are we even remotely capable of executing such a restful pause? In March 2023, over 1,100 notable people,<sup>90</sup> including tech giants such as Elon Musk, Steve Wozniak and Tristan Harris of the Center for Humane Technology, signed an open letter organized by the Future of Life Institute calling on ‘all AI labs to immediately pause for at least six months’. No such pause occurred and work on developing and training AI has pushed on inexorably. Concerns and calls for regulation continue to grow, but they are outpaced by the breakthroughs in AI. A pause seems less likely than ever.

Charges of naivety are easy to make, especially when it comes to the way we think about highly disruptive technology, entrenched conflicts or significant political challenges. But naivety and cynicism are not the only modes of thinking on offer. We are smart enough, surely, to think beyond our initial anxious reactions, compulsion to seek comfort, or autopilot thinking. It has always been hard work to think long-term and it feels overwhelming for many of us, but I hope this chapter has shown you that we need not be a slave to our fight-or-flight response or desire for instant gratification; we can train our anterior cingulate cortex to take the longer-term and wider view.

That’s easier if we are part of a larger collective consciousness, with a support network in place to help us resist the immediate reward and bring different perspectives, and the clarity that comes with a wider cultural context. We will need to take a leap of faith in ourselves if we are to practise long-term thinking in an age of short-term crisis. As the legendary music producer Rick Rubin says in his book *The Creative Act*, belief is everything; it is the ‘reality distortion shield’<sup>91</sup> that can actively shape reality: ‘We are required to believe in something that doesn’t exist in order



to allow it to come into being.’ Perhaps what we most need is to believe in our capacity to intelligently consider how we want to progress.

## **|EXERCISES|**

A brain fit for the 21st century is ... able to delay immediate gratification and see things from the perspective of our ancestors and descendants

- Create short-term incentives to bolster your long-term thinking. Support yourself to make longer-term decisions by implementing reward substitutions: a series of smaller rewards distributed along the path as you move towards your longer-term goals. For example, if the goal is saving for your grandchild’s education while also cutting down on your carbon footprint, take pleasure in planning lots of short, inexpensive but fun excursions with local friends rather than having that one big expensive holiday abroad.
- Practise mindfulness and meditation. Take some time every day to sit with your thoughts, trying not to react to them other than with curiosity or quiet observance. This practice increases high-speed gamma-wave activity in your brain, helping you to think at full brain power and access all the information stored across disparate brain regions. This will make it easier not to act impulsively with just one brain region urging you on. It also brings oxygen to the anterior cingulate cortex, the brain region behind your forehead that, as we have seen, helps you horizon-scan and innovate for the future. Taking time out to sit quietly can also help you to think more expansively and be more aware of the present, as well as helping you to develop strong coping strategies for stress, which, as we know, is highly detrimental to long-term thinking. Other effective stress-management techniques include exercise, engaging in a hobby or catching up with friends.
- Be aware of bad habits. Pay attention to feelings of guilt, remorse or disappointment. These emotions have evolved in our brain to highlight damaging behaviours in order to help us replace them with healthier habits. Such unlearning requires hard work and patience, so help yourself through this difficult process by surrounding yourself with people who clearly show



that they can delay gratification in their own lives and who are able to make an intelligent analysis of anticipated risks and rewards. Find role models who exemplify patience and long-term planning and try to spend time with them.

- Continue to exercise your imaginative skills but this time in the temporal dimension – imagine yourself as a Time Lord travelling back from the future. What decisions would your future self make? How would you structure your life now so that your future self and your future descendants might benefit?

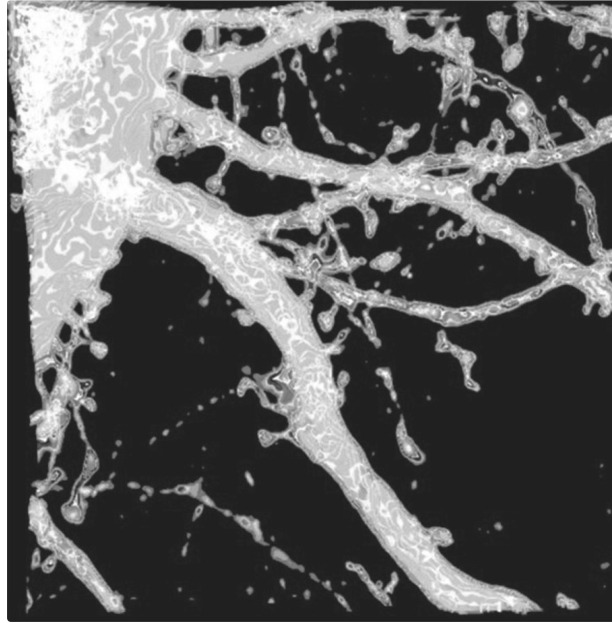
- If you catch yourself acting in a way that makes you feel angry or distressed, hit the pause button, breathe in deeply for five seconds, hold your breath for five seconds and release it over five seconds. Repeat this cycle until you start to relax and begin to regain control over your responses. If you do not feel able to calm down, take yourself out of the situation or find a distraction. Later, when in a peaceful environment, continue your breathing exercises and try to reflect on why you felt that way. Might there be some experiences from your past, or even your ancestors' past, that have primed you to be frightened or stressed by this situation? If so, is it useful to have this response? What is it trying to teach you? What use does it serve now? Being conscious of this physiological process is key to being able to act with the best long-term interests in mind. If somebody you know reacts to a situation in an unreasonable way, try to not get dragged in and cause things to escalate. Practise the breathing exercise instead while simultaneously engaging your empathy skills and trying to understand their response.

- Consider your home space and work environment. How do they make you feel? How in touch with nature are you there? What can you do to boost your brain health in these environments? Maybe even reconsider the benefits (or not) of working from home. Can you create a routine where you access nature every day to help calm your mind and enhance your creativity, engagement and longer-term thinking? Or it might be simple changes to the space you occupy, like letting nature into your rooms by introducing houseplants or making room for a daily walk in your lunch break, stopping to talk to people on your way.

## Adapting to Uncertainty

TWENTY YEARS AGO, MY WORKING LIFE was steeped in the neuroscience of change. My doctoral research was focused on learning more about the disruptions to perception that characterize schizophrenia. The overall aim was to help with the development of new drug treatments for the condition, and much of my time was spent peering through a microscope at slices of brain tissue or observing neurons in a Petri dish. I was studying the biological rules that govern how brain cells forge connections while adapting to the genetic and chemical changes I was applying (see the image on [page 154](#)). The cellular basis, in essence, of how the individual human brain responds to the ever-shifting dynamics of its environment. This constant adaptation was mesmerizing to watch.

I didn't anticipate the big changes that were about to impinge on my work, however, bringing with them a climate of deep uncertainty. In 2007, around the time I was completing my doctorate, a major shift hit the field: the big pharmaceutical companies that funded most of the research, including my own, began pulling out of neuropsychiatric investigation. Despite their massive investment, the magic-bullet drugs weren't materializing and the commercial return didn't justify the cost. Funding dried up and the pipeline of research trickled to a halt. Suddenly there was no future in neuropsychiatry.



**Nerve cell connectivity showing the diversity of dendritic spines in nerve cells from the hippocampus, grown in a Petri dish, and labelled with fluorescent dye. These extend out of a nerve cell, finding connections with neighbouring cells so that they can communicate and transfer information between each other. Dendritic spines are dynamic and highly flexible, changing shape to correspond with the processes of learning, remembering or forgetting.**

Ever since I'd worked in an acute psychiatric hospital as a teenager, I had wanted to contribute to making these often devastating conditions more amenable to treatment. After a decade of study, narrowing my focus to translational neuropsychiatry, I suddenly found that the path I had envisioned was no longer viable. The career I'd prepared for no longer made practical sense. It was a tough realization. How could I let go of a certainty that had guided every move I'd made since the age of eighteen? How should I make smart decisions about what to do next? I remember feeling disappointed, frustrated and wrong-footed. It was unsettling to realize that the professional basis on which I had hoped to build my life,

along with the sense of identity and purpose I'd imagined for my future, was crumbling.

After a few months taking in the changing job landscape, I realized that I could in fact stay in neuroscience, but I needed to pivot towards a new field. I was already drawn to science communication and policy, so I began to speak about brain research to a wide range of people, from business leaders to policymakers. If there was no wonder drug on the horizon, then it was even more important that the findings in neuroscience we *did* have were communicated clearly, especially to the public. If we were no longer chasing a magic pill, we would have to focus on creating environments that help our brains to flourish. Individuals, communities and organizations needed to understand the science well enough to use it to support learning, build resilience and promote mental well-being in everyday life.

I wasn't the only one who was forced to change course. One colleague retrained as a secondary-school science teacher; I later bumped into him while giving a talk to students at his school. Another became the director of a scientific journal. Someone else went on to launch an AI-enabled company that repurposes existing drugs for rare conditions. (More on him in a later chapter.) Navigating the uncertainty was difficult and might have turned out very differently, but we each found new ways to carry the science forward by adapting our thinking and behaviour. The nerve cells in our brains were forced to be agile, to forge new connections, enabling us to learn new skills, perceive new opportunities and assess different sets of rewards as we evolved with the situation. I learned how to change my mind about what was possible and valuable. Feelings that might have settled into disappointment and self-recrimination powered a new stage in my life. I learned resilience and self-reliance and how to cut loose a project (or indeed a whole discipline) if it wasn't working.

No doubt you've had a similar experience, at some point in your life, of having to navigate the uncertainty that comes with change. It might have been triggered by losing your job or by a health crisis; or perhaps it felt more benign – if you decided to move abroad or have a child, for example. Even changes we have chosen can throw up complex emotional challenges when we're out of our comfort zone. Or perhaps it's not so much that things are changing as that they're hard to read. Ambiguous situations create confusion. Feeling unsure or having mixed emotions can create significant feelings of uncertainty.

Whatever the cause, the blend of negative emotion and confusion that uncertainty often provokes in our brain makes it more difficult to think slowly, clearly and calmly. Analysis becomes more taxing, as does intuitive or creative thinking. Our brain must work harder, which creates fatigue, and contributes to a sense that we're losing agency. All of that can feel profoundly unpleasant.

We often treat uncertainty like a puzzle we must solve or a threat we need to vanquish, but that approach increasingly feels to me like the wrong one. For a start, it implies that we can do away with uncertainty if we are smart and tenacious enough, when it is an inevitable constant in our lives that cannot be outwitted. And secondly, our aversion to it, while deeply ingrained in how we have evolved to think, is not the last or the best word on how to live with change and ambiguity. There are more intelligent ways to think about these age-old realities, and it's becoming urgent that we learn how to adopt them.

In this chapter we will be building on what we've learned about risk assessment and imagination, the corrosive effect of stress and the protective effect of reflection. We will apply it all to the notion of coping with uncertainty, which poses one of the greatest challenges to our individual and collective ability to thrive into the next few decades.

First, an acknowledgment that, while we may feel we are living in particularly uncertain times, this sensation would doubtless be familiar to our forebears. All generations are probably doomed to bewail the difficulties of their era. The alleged traditional Chinese curse 'may you live in interesting times' or the opening line of Charles Dickens's *A Tale of Two Cities* – 'It was the best of times<sup>1</sup>, it was the worst of times' – serve to remind us of this. Uncertainty is a basic philosophical problem that is part and parcel of being alive, since none of us know whether today will be our last. Our discomfort with uncertainty operates at every level, from the existential to the cellular.

But just because it's a challenge as old as humanity, doesn't mean it isn't getting tougher to deal with. Uncertainty is inevitable in situations that are dynamic, complex and unpredictable, when change occurs rapidly and with little notice, and when we have something to lose. Tolerating it, as with thinking longer-term, is an aspect of our sophisticated cognitive behaviours that is crucial to success and yet is under pressure from accelerating

technological change and undermined by a highly volatile social, political and economic environment.

Our world is changing fast. Can we develop the capacity to change with it is one question, but a deeper one might be: can we learn not merely to cope with uncertainty but to thrive in it? Can we take on board the idea that change and ambiguity are not automatically and intrinsically threatening?

We may know this in theory, but few of us behave as if we do. Most of us dislike uncertainty, some of us dread it and plenty of us try to avoid it, but given that change is a necessary condition of life itself and our biology dictates that we are changing all the time, we can't avoid it. It would be impossible to engineer uncertainty out of our lives even if we wanted to, and who would really want to when to sacrifice it would mean the loss of growth, discovery, creativity and novelty? The only intelligent answer to the problem of how to live with uncertainty is that we must figure out how to become comfortable with it, and begin to see it as an opportunity and even an ally.

It is possible to boost our tolerance for uncertainty and learn to change our minds, switch course and adapt. The rewards of doing so are huge. The sector-wide shift away from neuropsychiatry twenty years ago, for instance, turned out to be an example of successful flexible thinking and canny risk analysis. As Dr Thomas Insel, former director of the Institute of Mental Health, admitted in 2017: 'I spent 13 years really pushing on the neuroscience<sup>2</sup> and genetics of mental disorders, and when I look back on that I realize that while I think I succeeded at getting lots of really cool papers published by cool scientists at fairly large costs – I think \$20 billion – I don't think we moved the needle in reducing suicide, reducing hospitalizations, improving recovery for the tens of millions of people who have mental illness.'

I don't believe the money or effort was wasted; the work that was produced may yet lead to breakthroughs, not least now we have the assistance of sophisticated large-language-model-based AI to help us reinvestigate the data. But I do believe that we shouldn't pin our hopes on such tech or abdicate our responsibility to do hard cognitive work ourselves. We must adapt to changing circumstances and train to be ready for our future. Just as the magic-bullet drug we were searching for back then proved elusive, so might the tech-enabled changes we long for now. In the meantime, it is more important than ever to be the agent of our own

success and well-being. We can do a lot to help our brain to flourish in uncertain times.

## Uncertainty tolerance – the science of how our brain reacts to change

Monitoring, analysing and reacting to uncertainty is exhausting for the brain, which has evolved to perceive patterns and foster habitual behaviours to save both energy and time. Such patterns of behaviour act as shortcuts. You did not, for example, need to work out how to sit down, open your book and turn to the correct page just now; you automatically did these things without being aware of coordinating your movements, because they were all so familiar to you. Any new or confusing information that's going to require energy-draining analysis and possibly a novel response represents a problem for our brain, even before it gets to assessing whether it's a threat or an opportunity. That's why it loves the familiar, and why routines and habits are so comforting. They literally feel safe, on a deep cognitive level, as well as helping to create pockets of time where we can indulge in the mind-wandering that we discovered to be so necessary for our brain health and creativity in previous chapters.

Dealing with uncertainty and initiating change is not only exhausting but unpleasant, even painful. Uncertainty evokes a sense of loss, fear or of being overwhelmed and (thanks to the familiar foe of negativity bias) is linked to dwelling on negative emotions<sup>3</sup> rather than thinking of the positives. Unpredictability and uncontrollability are central features of stressful experiences<sup>4</sup> that are all but guaranteed to make us feel unhappy<sup>5</sup> and lacking in agency.<sup>6</sup> And the discomfort is not confined to emotional distress or mental stress; it can also be perceived as physical pain. In fact, studies have demonstrated that being in an unpredictable environment makes physical pain feel worse.<sup>7</sup> In 2016, Professor Ray Dolan and colleagues at University College London conducted a slightly mean experiment, delivering mild electric shocks to people while measuring heart rate and sweat and salivary cortisol levels. They discovered that the subjects were generally calmer and less agitated when they knew for sure that they were going to receive an electric shock, than when they knew there was a



50 per cent chance that they might. In some cases, people preferred to bear a financial cost in exchange for the certainty that they *would* receive a shock. That double pain – of losing money and being given a mild shock – was still preferable to the 50/50 ambiguity. Similarly, a study of over 1,500 adults conducted<sup>8</sup> over a decade discovered that the threat of job insecurity is much more detrimental to health than losing a job. In short, for most of us an uncertain situation is harder to bear than facing the worst.

Any kind of aversion will have its pros and cons in terms of behaviours and outcomes. Being averse to risk, as we saw in the previous chapter, makes it more likely you'll dodge a sudden end but increases the likelihood of your slowly dying of hunger when the berries run out; or, more plausibly these days, your chance of missing out on intriguing opportunities. As with risk, so with our tolerance for uncertainty. Having a low tolerance means we avoid many of the downsides of risk and might be more decisive, but it could also lead to anxious rumination or jumping to the wrong conclusion. And while there is a general aversion hard-wired into our brains by evolution, there is also a great deal of individual variation in comfort levels and coping strategies.

Some people run towards uncertainty, actively driven to be change creators. They would rather try to take control than be affected by a change they did not initiate or an ambiguity they couldn't live with. Other people feel the effect of uncertainty as a low background rumble of worry, or as the jitters of excitement. Some of us become stressed, paralysed by indecision, snappy with colleagues or desperate for resolution, even if that means the sort of unsuccessful outcome that Ray Dolan's unfortunate test subjects opted for. None of these responses is conducive to reflection, analysis or good decision-making. They tend to make us less capable of evaluating information and more prone to assumptions, bias and a narrowing of focus. Being anxious, as we know, generally creates the very worst conditions for smart thinking.

Knowing more about how different people's brains handle uncertainty at a cognitive level allows us to consider potentially valuable behavioural strategies, as well as be more aware of the risks that come with low tolerance for uncertainty. Over the last couple of decades, neuroscientists have been examining the neural circuits involved in monitoring and reacting to uncertainty. Another relatively new field of research for them, like creativity, it is providing fascinating insights into the inextricable links

between perception, reward, risk assessment and decision-making. As with so many aspects of human behaviour that were previously the exclusive province of behavioural psychologists, it turns out that our tolerance for uncertainty is not only measurable but rooted in specific brain regions and neural dynamics. Being able to cope with uncertainty is a complex, foundational cognitive skill that supports and rewards many of our optimum behaviours, like innovation and learning, not to mention our mental health and mood. Low tolerance for uncertainty, on the other hand, is closely connected to biased or deluded thinking and at its most extreme has even been linked to schizophrenia, which scientists suggest could be construed as a condition underpinned by an inability to effectively gauge uncertainty.

After the pharmaceutical companies withdrew from research into schizophrenia, a handful of academics, mostly funded by governments or charities, kept on working. One such group is based at MIT and has been funded by the US National Institute of Mental Health. They discovered brain circuits that act as a crossroads, helping to guide decision-making under conditions of uncertainty, and identified specific nerve cells that send stop signals to prevent the brain from using unreliable information. In people with schizophrenia these circuits are almost inactive. The researchers published their findings in the journal *Nature*<sup>9</sup> and believe these could help develop new treatments. One of the study's authors is MIT Associate Professor of Brain and Cognitive Sciences Michael Halassa, who is also a practising psychiatrist. 'A lot of cognition is really about handling<sup>10</sup> different types of uncertainty,' he explained. 'In my mind, schizophrenia spectrum disorders are disorders of appropriately inferring the causes of events in the world and what other people think.'

We will be exploring psychosis and the strong beliefs, hidden messages or paranoid thoughts that typically accompany the condition when we meet patients in the next chapter. But for now, the idea that schizophrenia might arise from an inability to analyse the complex, ambiguous and confusing data that the brain is perceiving indicates to me how crucial this core skill of uncertainty tolerance is for our health, happiness and overall intelligence.

Most of us, blessedly, will not develop debilitating conditions like schizophrenia, but psychosis, delusions, belief in conspiracy theories, rigid thinking based on cognitive biases, and addictions will afflict many of us, as will anxiety disorders, which have become an epidemic. All these conditions could be considered the result of the brain's inability to manage

uncertainty. They might be said to exist on a spectrum that runs from collapse into confusion and untethering from reality at one extreme, and the construction of rigid certainties and habits at the other.

Being able to tolerate uncertainty seems to matter for everything, from our fundamental brain health to our career choices, but given that it's a complex state involving multiple brain regions and countless circuits, it's no wonder we find it challenging. It's also one of those submerged cognitive skills that has received relatively little attention. Unlike creativity or thinking long-term, where benefits are clear and the perils of a lack of skill are more obvious, we tend to overlook or take for granted the role played by uncertainty tolerance. That's why taking it seriously as a rising challenge or a potential breakthrough in twenty-first-century human intelligence is so important.

The Romantic poet John Keats coined the term 'negative capability'<sup>[11](#)</sup> to describe the unusual capacity of an exceptional thinker: 'in uncertainties, mysteries, doubts, without any irritable reaching after fact and reason'. As someone who venerates fact and reason, I can nevertheless appreciate Keats's precise use of the word 'irritable' to describe the way we sometimes grasp at certainty as a form of defence against our doubts, closing our minds to the potential of uncertainty. Keats thought that the capacity to tolerate ambiguity and seek creativity and opportunity within it was a mark of great intelligence. I agree, and so does contemporary neuroscience. The opposite can be disastrous for personal well-being and the collective smartness of a culture.

## Seeing possibilities: perception and ambiguity

As the scientists working to understand schizophrenia in terms of catastrophically low capacity to tolerate uncertainty have shown, the skill begins with perception. All our success in life rests on our brain's extraordinary ability to create the stable representation of reality in which we exist. The fact that most of us wake every day to the same consciousness of self, others and the environment around us, which we can see, touch, hear, smell and taste, is either banal or miraculous depending on your point of view. Perception is the substrate of our world and the beginning of all thought and all behaviours. It's also a gargantuan neurological task, involving real-time analysis of the torrent of data secured by our five

external senses and interoception, our sixth internal one, and the manipulation of that information into a bespoke picture of our environment.

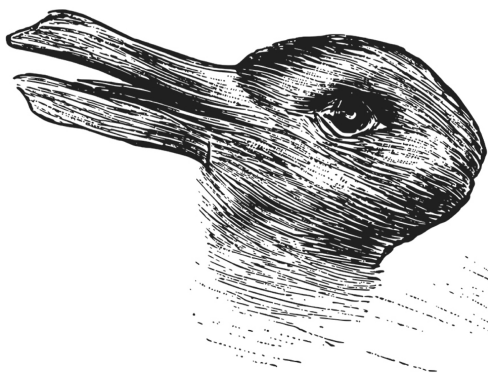
Our brains, as we have seen, are bombarded by something in the region of 11 million bits of data per second,<sup>12</sup> transmitted from our senses into our central nervous system. We can only be consciously aware of a minuscule proportion, roughly 50 bits per second. How on earth do we filter out the unnecessary noise while prioritizing the important bits, and then construct a credible model of reality from what we receive? The answer is, by making it up out of best guesses. Each person's brain constructs their version of reality in accordance with the genetic inheritance that shapes neural circuits and the experiences that go on to further sculpt and fine-tune them. In essence, we see the world through a prism of biological determinism and past occurrences. Our brain creates a template of expectation, so that it can propose a believable simulation of the current situation, prepare us to respond and, ultimately, stay alive.

I find perception mind-boggling, both biologically and philosophically, and yet I also take it for granted, as every human being must if they are to get on with their life. So many of its operations are automatic and unconscious. It's only really when it goes awry that we notice it at all. What's that funny smell, or that blurring of my vision? Why am I hearing rather than seeing colours? Is that figure over there real or imagined? For the most part, our brain supplies us with a perfect 3D simulacrum of reality and encourages us to trust it so that we can get on with hanging the washing out or writing an ode to beauty. Your brain does this all the time, as does every animal's brain, and yet it's little short of miraculous.

Disruptions and ambiguities in what we're perceiving are unsettling for good reason: they signal potential threat, either in the external environment or within the brain itself. Even if there is no tiger hiding in the bushes, the uncertainty itself is undermining the brain's capacity to analyse, predict and do one of its most fundamental jobs: build a model of the world. What are its preferred ways to resolve such ambiguity and return to the certainties of stable reality? It could seek more information or process information more thoroughly<sup>13</sup> to find answers, but both of those require energy outlay and take time, so the brain frequently resorts to shortcuts and assumptions, relying on good-enough modelling, predictions and learned behaviour to get the job done. One great example of making shortcuts in information-processing for our survival stands out: think back to our ancestors' day

where dangerous predators may indeed have been lurking in the undergrowth. The shadows of leaves may or may not have been concealing a tiger. No wonder our brain has evolved to preferentially ‘see’ that pattern in order to fire up the flight response. It’s not worth the risk of seeking out more information or sticking around to ponder the data more deeply. Our ancestors took to their heels and survived to live for another day.

Our uneasy relationship with feeling unsure makes sense when you consider that uncertainty signals that something in our environment is resistant to the brain’s prediction-making. The stakes might be quite small or very high, but only further investigation will determine which, and in the meantime the uncertainty continues to pulse out its warning, which feels anywhere between unpleasant and intolerable, and all the worse for being open-ended. No wonder we would rather accept a painful electric shock than live with the threat of its possible arrival.

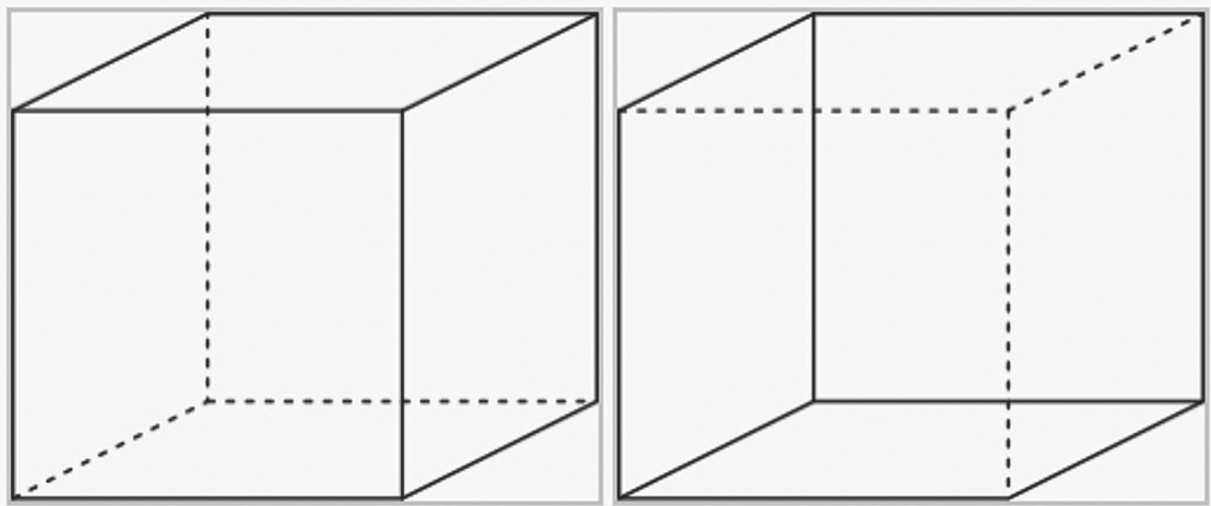
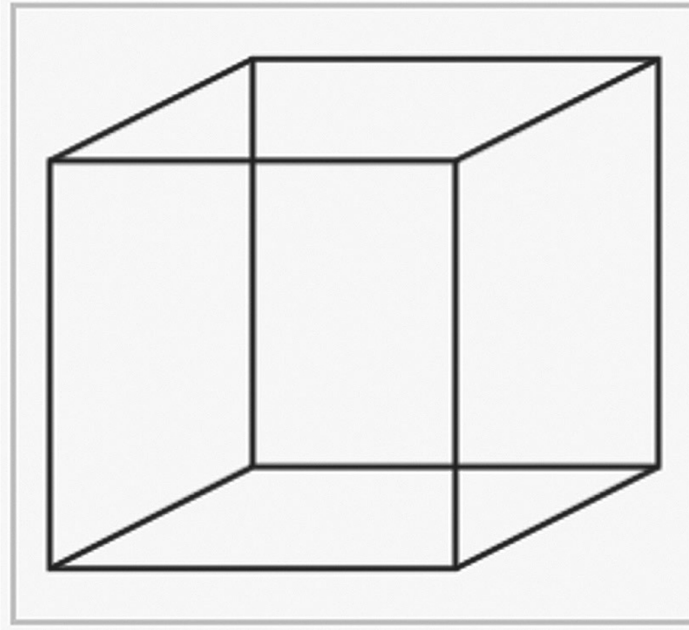


**In these ambiguous images,  
with no cues, what do you  
see?**

To illustrate the brain’s primary drive to turn uncertainty into certainty, take a look at the ambiguous illustrations above and on [page 167](#). In the absence of more information, your brain will work harder with what it has and fill in the gaps to come up with a credible interpretation. You might see, in the first illustration, either a duck or a rabbit. In the second you may see either a cube popping backwards or one with the front edge facing the top right-hand corner of the page.

In this instance, of course, it doesn’t matter whether you see a duck or a rabbit or a cube of one sort or another. There is no better, more accurate interpretation. Your brain has simply resolved the deliberate ambiguity one

way or another so that you can move on from perception to some sort of processing and reaction: dredging up a memory that involves cute bunnies, perhaps, or realizing how fascinating perception is, or wondering whether you should take a drawing class. The point is that if you tell yourself you're looking at a rabbit, you'd be right, but not completely. The rabbit is to a certain extent a fiction that your brain has concocted, no more or less real than the duck your neighbour sees. The fact that everything we perceive of reality is actually a model made by guesswork as a cover for uncertainty raises interesting questions. How can we ever be certain about anything, once we know that it's a necessary fiction?



**The two possible interpretations of the Necker cube (an optical illusion created by Louis Albert Necker in 1832) with the cube appearing to pop forwards or backwards. Can you flip between the two different perceptions when you look at the original image of the cube?**

The capacity to see both rabbit and duck without prompting, and toggle between them with ease, is not that common, by the way. Less than 3 per cent of test subjects can see both<sup>14</sup> the rabbit and the duck in the same image. But now you've seen both options, how easily can you switch between the two? The ability to change perspectives under uncertain or ambiguous conditions appears to be associated with creative problem-



solving.<sup>15</sup> If you can switch between the two interpretations almost automatically, you're probably more open to the evidence of what you're actually seeing and less dependent on prior exposure to similar drawings. You may be creative and more flexible in your thinking, since fluid perception enables the brain to interpret the world openly.<sup>16</sup>

Intrigued by a study published in 2012 by Andrew F. Jarosz and colleagues from the University of Illinois, Chicago, titled 'Uncorking the muse'<sup>17</sup>, I tried these optical illusions after a few alcoholic drinks, to see if that would boost my ability to slip between interpretations. I nodded along when I read that the authors concluded that mild inebriation might help creative problem-solving by increasing flexibility in perception. That's always been my experience. Mind you, the necessary caveat (and one I learned the hard way) is that Jarosz and his team also found that intoxicated individuals were more likely to rate their solutions as insightful. So it's probably best to sober up and re-evaluate a perception before following through on a drunken Eureka moment.

While many of perception's mechanisms are not under our conscious control, the interpretations it gives rise to very much are. How you assess, describe and interact with reality is up to you and is amenable to all the many techniques for smarter thinking that we've been examining. Once you know that uncertainty is baked into our understanding of the world, you can decide which way to travel in response. Will it be towards the potentially false comforts of certainty. ('It's definitely a bunny and everyone who says otherwise is plainly mad!') Or towards the opportunities inherent in ambiguity? ('It could be a bunny but might it be a duck? You think it's a zebra? Interesting ...') When you come across a piece of information, a story or a situation that puzzles or unnerves you, it can be good to pause, reflect and ask yourself questions about what you're encountering, as well as your prior assumptions. In this way, curiosity leads towards possibility, novelty and growth. If it all gets too alarming, you can always return to firmer ground.

## Gathering information as a winning strategy

Having established that uncertainty is a cognitive challenge for our brain at the most fundamental level of perception, it's time to consider the

implications for our conscious thought processes, behaviours and self-conscious relationship with uncertainty. It's a given that human beings generally dislike and distrust uncertainty, for good reason, but that's only the beginning of the matter. How we respond is the crucial determiner of outcomes.

Let's consider information-gathering as the first response. As we saw in the last chapter about risk assessment, finding out more about what you're dealing with is a fundamental cognitive strategy that the brain also deploys when it's trying to do its job of perception, and which we adopt as a conscious behaviour whenever we come across something new, unexpected, complex or ambiguous. It helps us to combat the cognitive biases that we've accrued from previous experience, and to spot new opportunities. It's so instinctive that an infant does it, by grabbing, touching, tasting any puzzling or exciting new object it encounters. It's an everyday tactic for reducing uncertainty that underpins investigation and learning at every stage of life and in every situation, from that inquisitive baby to a team of engineers or business leaders.

In November 2024, I spoke at an event in Germany in front of forty executives of BASF, a leading global chemical company that was facing change. One object of the gathering was to explore how to plot a course towards commercial success in light of recent geopolitical events and consumers' growing focus on sustainability and health. On stage with me was Mark Gallagher,<sup>18</sup> formerly a senior member of the Red Bull Formula One (F1) management team and the author of *The Business of Winning: Insights in Transformation from F1 to the Boardroom*. 'Formula One is an uncertain environment,' Mark began. 'We go into a race knowing that there are some things we can control but far more that we cannot. And we have to adapt to those things, as and when they happen.'

Gathering as much information as possible is crucial to the F1 teams' ability to adapt. 'Both Mercedes-Benz and Red Bull, the teams that have dominated F1 over the last fifteen years, constantly review performance,' Mark told us. 'It's relentless and very data-driven. They ask, "How did we win today? What did we do right? We won the race by five seconds but the data tells us we could have won the race by twenty-five. Where did we lose that margin?" We learn from our successes and our failures. There is a deep curiosity within winning teams.'

Having access to more information sounds like an obvious advantage, but given the brain's constant vying with overload, it isn't the case that more is always better, especially in a fast-paced and high-risk environment. Neither is all information created equal. What *kind* of information, from which kind of source, matters immensely.

Mark elaborated on various specific strategies for information-gathering. Firstly, information from a real-time bird's-eye overview can be immensely useful. Mark told us about Michael Schumacher, who famously trained himself to watch the giant TV screens positioned on the side of the track for spectators while he was driving in the race at 330 kilometres per hour. Why would he engage in this fantastically risky behaviour? Because it allowed him to pick up a huge amount of extra information about what his opponents were up to: information he couldn't obtain from the vantage of his own car, and which allowed him to adapt, keep his competitive edge and continue his winning streak of five consecutive world championships.

Another specific strategy that Mark discussed was seeking out knowledge from diverse experts in different areas, thereby increasing the breadth of information available. Working in a group is a highly effective way of avoiding the tendency of any individual to fall back on prior knowledge and into bias. Working in a group of people with *different knowledge who trust one another and communicate openly* is a well-established recipe for success. The problem is that a team that is more socially diverse (comprising men and women, for instance, or people from different ethnic and economic backgrounds, different disciplines or areas of expertise) and with greater cognitive diversity (people of different ages, for instance, and with varying kinds and degrees of neurodivergence) will have to grapple with lower levels of trust and more uncertainty and ambiguity as they engage with one another. Our brains, as we have seen, are inherently lazy and biased and we are hard-wired to find it easier to understand and get on with people we perceive as similar to us. A more diverse team can mean an increase in the amount of social friction between members. Respect, honesty, active listening, an agreed framework for dealing with difference of opinion and conflict all become more necessary. Otherwise, the proven gains from increasing the diversity of perspectives among team members are lost amid an inability to work together harmoniously.

So much for increasing the amount of information available from our external senses. What about turning inwards to make use of our internal

resources? As we saw in [Chapter 1](#), our intuitive or interoceptive ability to tap into a hunch can help us to make intelligent decisions, especially in a rapidly changing environment.<sup>19</sup> The amount of information is always too great for our brain to transform it all into conscious thought, so some incoming signals end up being processed across the peripheral nervous system, available for us to draw on in the form of a gut instinct. This seems to be especially true in situations of uncertainty, where fast thinking via instinct has been shown to be highly effective. Mark mentioned how Schumacher frequently noticed things that might have influenced a race, or that could be tweaked for next time, faster than other team members. As someone who had been trained to stay alert and responsive in the mother of all fast-changing situations, it would make sense that his interoceptive abilities were highly tuned. Absorbing information from a TV screen while driving at 330 kph seems a little extreme but, as we learned from Professor Sarah Garfinkel in [Chapter 1](#) and Amy in [Chapter 2](#), there are exercises and games we can play that help to develop our abilities.

Finally, the forms of thinking we deploy when we're assessing risk are highly relevant when we're trying to tackle uncertainty through information-gathering and analysis. Using our imagination to envisage worst- and best-case scenarios and run through hypothetical situations in our heads can help us to adapt to uncertainty when we encounter it, keeping us calm and making us more confident about decision-making. This too is exactly what the F1 teams do: they prepare for both the best- and the worst-case scenario and rehearse procedures for each.

Gathering information in the present to be better prepared in the future counters two cognitive biases that at first sight appear contradictory but often complement and enhance each other. As we've seen already, there is an inherent negativity bias that accrues when we're assessing risky situations, which can make us too risk-averse. There's also an optimism bias. Individuals tend to be more optimistic about their own future<sup>20</sup> than a comparable person's (known as personal optimism bias) and this extends to people or social groups they identify with (social optimism bias). These biases operate like a form of wishful thinking that blinds us to rational analysis when our desires and interests are in play. Put simply, we want the best to happen for ourselves and those like us. As a result, we risk tipping into magical thinking, where we confuse what we want to happen with what will happen. That can leave us floundering when challenging times arrive.

Being underprepared for any scenario is not acceptable in the arena of Formula One, or indeed risk analysis for insurance companies. Sally Bridgeland is an award-winning actuary who has been responsible for billions of pounds' worth of investment. Describing herself as 'a big, big fan of scenario-testing'<sup>21</sup>, she applies it to practically every situation she encounters professionally. 'One of the things we do is "reverse stress testing",' she told me. 'We ask, "What would have to happen for the insurance company to go under; basically, for there not to be enough money to pay the policy holders?" It's an important part of the regulatory environment for us to understand the risks we run as a business, because if we fold, we can't cover people for *their* risks.'

Sally described to me some of the fancy models that test the causality and probability of different domino effects of events that would result in catastrophic business failure. But her favourite tool for this kind of analysis of uncertainty? 'Lots and lots of yellow Post-It stickers,' she replied, with a grin. 'I ask, "What are the biggest things that could go wrong?" I put each one on a sticker and work backwards and outwards, layering other stickers in, moving them around to test which pivotal scenarios or problems act as hubs. These become the "Doom Stickers", the ones that cause ripples and trigger escalations. I use the map to figure out at which point you might have the opportunity to steer a situation away from catastrophe.'

She can visualize and classify different risk tolerances to identify where management actions can lead to a recovery or when quitting is the only option. 'You're adding a huge amount of resilience by doing this thought exercise ahead of time,' Sally told me. 'It's building the cognitive equivalent of muscle memory for dealing with any crisis, for being agile and able to problem-solve. And in the process you've increased a tolerance for uncertainty by identifying where some of the intercepts are. It means you can stop worrying about it once you have a plan.'

Sally's maps of doom depict complex situations, but she's using a simple premise that we can all adopt: visualizing a scenario, imagining and playing out the permutations that could lead to failure and identifying the weak spots so that one can either strengthen them ahead of time or prepare to sound the alarm and abandon a sinking ship.

Cheerful, relaxed and assured, and describing herself as 'the opposite of a worrier', Sally applies the doom-mapping technique to her personal life as well. I came away from our conversation with the impression that her

pragmatic and enquiring approach to uncertainty seemed to be providing a high degree of both resilience and critical thinking. This helps her to view the world in a positive and enterprising way rather than a negative, paranoid one, while ensuring her thinking is rooted in analysis rather than supposition or wish-fulfilment.

## Avoiding delusional thinking: misinformation and conspiracy theories

When it comes to working in conditions of uncertainty, we're hampered in multiple ways. Our brain's deep aversion to it raises our stress levels and encourages us to adopt potentially inadequate coping strategies. Our inherently flawed system for perceiving and evaluating information makes us vulnerable to error. And then of course there's the fact that the raw material for resolving uncertainty may or may not be useful. After all, not every piece of information is pertinent and not all sources are reliable. If our brain is going to do a good job of turning uncertainty into certainty, it has to avoid jumping to the wrong conclusions and making the wrong assumptions, otherwise it can end up too rigidly attached to a certain viewpoint or incapable of having one at all. The brain needs a reliable way of distinguishing between viable data and data that is either not useful or downright unhelpful. It also needs to be able to evaluate its own workings and measure its conclusions against a generally accepted external framework. This is all sophisticated stuff. No wonder we often find ourselves floundering, falling back on forms of magical thinking, using personal rituals to try to secure an outcome, falling for misinformation or believing in conspiracy theories.

Some of the mild forms of delusional thinking are of course entirely harmless. Believing that visualizing your lucky numbers as the National Lottery is drawn will boost your chances of a big win, for example, is a form of magical thinking that many of us indulge in, with no damage done. But psychiatrists have linked more extreme manifestations of magical thinking to various psychiatric conditions, from obsessive-compulsive disorder to schizophrenia. As belief in conspiracy theory goes up all over the world and accusations of fake news and assertions of alternative facts are thrown around, we find ourselves living in an environment where reality

itself is increasingly contested. That makes it even more important to cultivate our personal cognitive stability so that we can consciously parse the torrent of information using critical thinking, rather than falling into harmful delusion.

There has been a surge in conspiracy theories in recent years. In his book *Voodoo Histories: The Role of Conspiracy Theory in Shaping Modern History*, UK-based political journalist and author David Aaronovitch defines a conspiracy theory as ‘the unnecessary assumption of conspiracy<sup>22</sup> when other explanations are more probable’. Examples might include the belief that the CIA planned the 9/11 attacks or that the coronavirus vaccine was used by Bill Gates as cover for the mass implantation of trackable microchips. In 2013, a team of psychologists at Goldsmiths,<sup>23</sup> University of London, developed a groundbreaking scale for measuring people’s tendency to believe in conspiracy theories and adopted Aaronovitch’s definition as their starting point.

Since that 2013 study there has been an explosion of interest among psychologists, and increasingly among neuroscientists, in understanding the cognitive traits that make someone more likely to believe in conspiracy theories. Noting that these ideas seem to crystallize around the same time as highly polarizing societal or political events,<sup>24</sup> and that such events have been shown to cause a physiological stress response, many researchers and commentators have speculated that they represent coping strategies for dealing with confusion and lack of control.<sup>25</sup> Accepting a conspiracy theory can help us reach an intuitive understanding<sup>26</sup> of a problem that might otherwise be too hard to solve, especially if it’s a novel issue for which the brain lacks a template<sup>27</sup> based on prior experience. Conspiracy theories tend to provide relatively simple explanations of new and complex issues, which means our brain can restore predictability,<sup>28</sup> albeit at the cost of suboptimal reasoning.

One of the many problems with relying on conspiracy theories is that, while they might make us feel less stressed, confused and out of control in the short term, over the longer term they have been linked to paranoid thinking and a decline in mental health. A study conducted in early 2024 by a team from the Institute of Psychology<sup>29</sup> at the Polish Academy of Sciences, for example, investigated the link between belief in conspiracy



theories and paranoid thinking. Their work suggested that, while the two things were not immediately or inevitably connected, there was a marked tendency for the one to eventually lead to the other, especially if the person's levels of emotional distress remained high.

In 2024, Dr Salomé Leclercq and colleagues,<sup>30</sup> who are based at the Neuroscience and Cognition Centre at Lille University in France, set out to untangle the complex relationship between perception, our tolerance for uncertainty and our sensitivity to environmental stressors. They wanted to know how this might be linked to a propensity to believe in conspiracy theories.

Leclercq's team carried out a very clever experiment using real-world data derived from how three geopolitically unstable situations had been perceived in their respective countries: the United States of America (the 2020 presidential elections), the United Kingdom (the 2021 Brexit implementation) and France (the 2022 presidential elections). There were more than six hundred participants in the study, aged between eighteen and sixty and evenly distributed across the three countries of interest. All nationals of their respective countries and regular users of social media, the participants were analysed with the same protocol one month before and then one month after the respective political event.

That protocol consisted firstly of filling out a sociodemographic form and completing the Generic Conspiracist Beliefs Scale (the pioneering tool developed at the University of London in 2013), which contains a series of statements such as<sup>31</sup> 'Secret organizations communicate with extraterrestrials but keep this fact from the public' or 'A small, secret group of people is responsible for making all major decisions, such as going to war.' Participants indicated whether they disagreed, were neutral or agreed with each statement. They were also asked to rate on a scale of 1 to 10 how distressed they were regarding the political situation in their country.

The participants were then asked to examine the diagram of the Necker cube optical illusion that we saw earlier. Their responses enabled Leclercq's team to assess how easily test subjects could switch between interpretations, which is considered a signifier of flexible perception. The subjects were instructed to passively observe the diagram of the cube, without attempting to adjust what they saw or force their perception. The cube was presented in this way a whopping 640 times, with a pause in between each time it was shown, and the participants were asked, on each occasion, to say which

orientation they saw it in. If a person has stable perception, their first view of the cube will inform subsequent interpretations: this prior information begins to act as a bias, strongly affecting their interpretation of further information, even if it has changed. Someone with unfixed perception, on the other hand, follows the flipping from one orientation to another more easily. They are displaying a more flexible way of viewing the world.

What conclusions were the team able to draw from tallying the scores for conspiracy belief with the results from the perception test, and by comparing the results obtained from before the political event and after it? Firstly, they discovered that rates of conspiracy theory agreement did not differ between men and women but were impacted by age: younger participants were more likely to believe in such theories than older ones. A striking factor uncovered by the study was the level of emotional distress experienced by participants. Those who tended to agree with the conspiracy theory statements rated themselves as less distressed by news of political events, suggesting that their beliefs were a form of coping mechanism.

The biggest factor, though, was the level of educational attainment. A higher level was associated with a lower susceptibility to conspiracy theory. This is in line with previous research, which has shown that having completed secondary education offers some protection against conspiracy theories, having a degree even more, and specifically some knowledge of science, technology and engineering subjects is helpful. (An interesting exception is that, for narcissistic people<sup>32</sup>, education may *increase* their likelihood of adopting conspiracy beliefs. Narcissists believe their superior knowledge and skills enable them to see information more clearly than others. One study of more than 50,000 people found that highly educated narcissists were more likely to believe in conspiracy theories than the average person, and this was linked to a reduced capacity for cognitive reflection and intuitive thinking. In people who don't display narcissistic tendencies, reflection and gut instinct, alongside education, seem to offer some degree of immunization against conspiratorial thinking, which narcissists miss out on.)

In her summary, Dr Leclercq referred to the link between heightened uncertainty caused by the pandemic, terror attacks and climate change, and the vulnerability of distressed people to misinformation and manipulation. High uncertainty that produces significant distress seems to increase our willingness to accept a potentially erroneous belief. That imposes some

order on our cognitive processing and gives us relief from the real suffering caused by uncertainty. The process takes place at a subconscious level, affecting the mechanisms of perception, as well as the conscious level of belief formation. ‘Gaining a better understanding of this phenomenon<sup>33</sup> has vast social implications,’ she observed.

For me, these results also point towards a conundrum, one that fell outside the scope of the experiment but which serves as a reminder that the brain is always engaged in a delicate balancing act between different modes of thought in order to maximize benefits and reduce drawbacks. As we saw earlier in the chapter, flexibility of perception is not always negative. It’s also strongly associated with creative problem-solving. Creativity often requires us to see a situation in a new light, to shift our perspective and think laterally so that we can discover a novel solution to a problem. But sometimes, especially if there is accompanying distress, that urge to seek out novelty overrides evaluation. Maybe uncertainty is akin to mild inebriation. If we are driven towards novelty under conditions that suppress critical thinking, we *might* come up with valuable insights, but we would do well to pause and consider them again when our thinking is less disordered by stress or alcohol.

Human beings are a social species; we love the comfort of being with people who think in similar ways to ourselves. Combine this with our natural propensity for cognitive laziness and the rising levels of geopolitical uncertainty all over the world and it’s not surprising that more of us are gravitating towards echo chambers of opinion and polarized misinformation. This is not merely a collapse into unreason; in fact, it’s a rational response to the strain of living with uncertainty. Rational but short-termist, and doomed to lead to further problems. A more intelligent approach would be to cultivate our critical thinking when appraising information,<sup>34</sup> while also exercising our interoception.

Fortunately, critical thinking is a relatively easy skill to practise. A simple starting point is to seek out different opinions, in conversation and in the media you consume. Listen to a new podcast, check out what people are saying about an issue in different parts of the world or read a news site of a different political persuasion. Remember that information we absorb at a slower speed, via reading or listening to audiobooks, is more likely to be retained and reflected upon than information we take in via screens. Reading the written word takes longer than looking at images but it has

provable benefits for cognitive skills. If you notice that your emotions quickly rise to the surface, take some time to regulate them. Step away, breathe deeply. Pause and reflect. Try to calm your sympathetic nervous system so that you can build your resilience to stress. All the skills we've been examining so far will feed your ability to think calmly and critically about opinions and theories rather than taking them at face value or rejecting them out of hand.

## Uncertainty training: what else is under our control?

Having a higher tolerance for uncertainty is undoubtedly a good thing. Like being able to delay gratification, it's one of those core cognitive skills that functions as a foundation for others. It protects against depression or compulsion and other disorders of 'stuckness' on the one hand, as well as delusional thinking, belief in conspiracy theories and paranoia on the other. If we can find the sweet spot between these maladaptive responses to uncertainty, then we can optimize our ability to be flexible and creative, seize opportunities and retain robust mental health amid change.

Beyond calm analysis of information, critical thinking, emotional regulation and tapping into interoception, what else might help us to boost our tolerance for uncertainty? Physical exercise, as we know, can boost neurogenesis in the hippocampus, underpinning our ability to imagine a way through the changes as a new world dawns. Meditation helps to engage our anterior cingulate cortex so that we can horizon-scan and accept ambiguity with greater ease, and walks in nature enhance our alpha waves so that we can think laterally about the possibilities that may open up.

Then there's the broad question of mindset. When I was speaking with Sally about her Post-It notes of doom, I sensed a positivity and resilience in her. It's obviously by no means scientific to assume that such a mindset is created by Sally's work on uncertainty, but her behaviours are associated with good outcomes in terms of mental health. Believing that uncertainty can be met with a spirit of enquiry and managed via calm analysis was working out for her really well. Sally exercises her curiosity about questions involving existential uncertainty, and curiosity seems to be a big

motivator for people who say they enjoy working in environments governed by complexity and unpredictability.

I met Dr Markus Kamieth at the 2024 conference on coping with change that I attended in Germany. The CEO of BASF, he opened the event by explaining: 'I'm always curious, I like change. I drive to create change rather than run away from it.' He then went on to speculate whether it might be possible to observe this trait under a microscope or via an fMRI scanner.

Not quite, but almost. In the section on creativity and those with ADHD in [Chapter 2](#), we saw that part of their make-up was a drive to explore new avenues and take risks in search of new solutions. Individuals with ADHD-like cognitive characteristics move towards novelty and forge change, creating new opportunities for their group, so it's not surprising that the entrepreneurial business world is full of people of this kind. One recent study found that those with ADHD-like traits<sup>35</sup> were approximately 1.7 times (60 to 80 per cent) more likely to be entrepreneurial in nature, and twice as likely to initiate entrepreneurial activities, than those without. Successful entrepreneurs have been shown to have a higher tolerance for risk than the average person and greater enjoyment of novelty. Their dopaminergic system makes them responsive to the motivation offered by change and to its potential rewards.

I'm not suggesting that we all need to become entrepreneurs, more that cultivating an interest in and curiosity about uncertainty can be immensely valuable and a spur to considered action. Asking questions and seeking a variety of answers allows us to hold our ground rather than retreat from uncertainty or rush towards resolution. We're back to information-gathering, and now trying to lace it with a healthy dose of emotional intelligence. If we can exercise curiosity rather than set out to prove we are right, we are training our adaptability and resilience as well as expanding our knowledge base and social network. We thus end up with many more resources for dealing with both the challenges and opportunities inherent in uncertainty. This process of leading with a spirit of enquiry rather than anxiety may require us to venture a little outside our comfort zone, but small efforts that reward us just enough without sacrificing all feeling of safety can be used as the basis for further exploration and greater potential gains. Pushing gently against the confines of our comfort zone by setting manageable goals to take us beyond it is a proven method for gradual behaviour change that we can apply to any area of our life.

One question that surfaced during that event in Germany was about the extent to which capacity to tolerate uncertainty is moulded by culture, in the sense of group dynamics created by established social norms. This is no small matter for a multinational company, of course, with employees all over the world bringing a potentially huge range of differing attitudes towards ambiguity and change. While we've so far been looking at the genetic and experiential factors that shape an individual's response to these conditions, there are also social and cultural factors to consider. Do people in, for example, Singapore approach uncertainty and implement change differently from people in, let's say, Germany?

The answer seems to be yes. Some cultures are more comfortable with ambiguity and more welcoming of change, seeming to thrive on it; others, less so. Geert Hofstede, a Dutch social psychologist and Professor of Organizational Anthropology and International Management at Maastricht University in the Netherlands, has carried out much of the groundbreaking work to identify cultural differences in a management context. 'Uncertainty avoidance' is one of the topics for analysis that he and his team use in their framework.<sup>36</sup> They looked at fifty different countries, giving them a score on what they called the 'Uncertainty Avoidance Index' (UAI), having carried out a meta-analysis of data related to individuals' rule orientation, their preference for a structured environment and strategies for coping with stress.

Some countries scored high on the UAI, indicating that people from those cultures are more likely to respect rules and authority figures and have a lower appetite for risk. Their societies enact more legislation and regulation to control uncertainty and mitigate its effects. Examples include Germany, Greece and Guatemala. Countries that scored low on the UAI include Singapore, Jamaica and Denmark. Here, the culture is more inclined to accept unstructured situations and changeable environments, and implement and stick to fewer rules and plans. Individuals are more inclined to a pragmatic approach, more curious, more prepared to listen to those of lower authority or social standing and place greater value on originality. The populations of these low-UAI countries<sup>37</sup> have lower reported rates of anxiety and stress. The UK, USA and Canada fall somewhere in the middle. As Hofstede observed when summing up the gist of his enquiry into uncertainty avoidance: 'The fundamental issue here is how a society<sup>38</sup>



deals with the fact that the future can never be known: should we try to control it or just let it happen?’

You had no control over the biology you were born with or the country you grew up in, but as you become an independent adult, you do have more liberty to choose who you spend time with. That gives you access to a significant lever for boosting your uncertainty tolerance, because group dynamics have been shown to have a profound impact on how an individual perceives situations, and on their cognitive behaviours. We now know that emotions and even moral values are highly contagious.<sup>39</sup> If one charismatic, highly enthusiastic person walks into a room<sup>40</sup> and begins to interact with others, their emotions, mindset and judgement have a measurable influence on the group. The higher this individual’s social status,<sup>41</sup> the stronger the contagion effect. Equally, fear, anxiety and anger can spread from person to person, both in the flesh and online.<sup>42</sup> Choosing to spend your time and attention with people who exhibit emotional intelligence, self-awareness and an open and curious mindset is one of the smartest moves you can make. It comes hand in hand with the responsibility to regulate your own emotions so that what you’re transmitting is similarly positive, both for yourself and the different groups of which you are a part.

There is a caveat to this plea for a positive mindset: if you’re feeling scared or angry, then your well-being and success depend on acknowledging those emotions rather than repressing them. Remember that emotions are data – they are potentially crucial information that can help you to steer away from uncertainty and the accompanying sense of paralysis or of being overwhelmed, but only if you work with your emotions. Your first task is to understand what they are signalling; the second is to figure out an intelligent response, either by harnessing any potential benefit before regulating them to minimize downsides, or moving straight to regulation.

We’ve talked about feelings of fear and the purpose they serve in the context of different behaviours, but less so about anger. Given the wide-ranging impact it can have on both an individual and a group, and given that it gets a consistently bad rap, one shouldn’t forget that anger can also be helpful. While its expression through violence of any kind is clearly unacceptable, the feeling itself is not. It can function as a clear signal that something unfair has happened, prompting one to react to injustice. It can be highly motivating, especially in conditions of uncertainty. If we get



frustrated because an obstacle has appeared in our path, for example, that can spur us on to make more effort. In situations where persistence is key, anger can be useful.

This was explored in a neat experiment into emotional reactions,<sup>43</sup> learned helplessness and attributional style carried out in 1988. Participants were first given an unsolvable puzzle to tackle and then a second one that could be solved. Mario Mikulincer of Bar-Ilan University in Israel wanted to know more about how individuals with different ways, or ‘styles’, of judging their own performance would react. His hunch was that those who put their success down to their own qualities (an internal attributional style, in other words) would get angrier than those who explained their outcomes with reference to factors outside themselves (an external attributional style), and that this would have an impact on subsequent performance. He was right. Those who responded with great frustration during the first round were highly motivated to tackle the second, persisted for longer and performed better. In contrast, those who were less reactive to the first unsolvable puzzle showed no improvement in performance on the second round. A little bit of anger, it seems, can be a good thing, at least if you tend to an internal attributional style.

There’s a big caveat here, though. Mikulincer followed up this experiment by presenting all the participants with a new series of four consecutive puzzles that were all unsolvable. Repeated failure to find solutions made those who had initially been more frustrated feel more depressed than the less reactive group. Less anger and less inclination to blame themselves for failure added up to less distress. So while anger is potentially useful for some of us in small doses and for a limited time, it is also associated with a propensity for emotional distress and, for some, can lead to poor judgement and impulsivity.

Unlike fear, associated as much with freezing on the spot as it is with reacting in panic, anger definitely tends to motivate people to act – for good or bad. In 2018, Dr Marien Lievaert and colleagues at the Institute of Psychology<sup>44</sup> at Erasmus University Rotterdam in the Netherlands investigated the relationship between anger and impulsivity in patients in forensic psychiatric units, whom they had previously assessed for levels of anger. They showed participants a series of pictures, some featuring angry faces or people fighting. Each picture had a blue or yellow frame. Participants were asked to press a button or not press a button, depending

on the colour of the frame. A blue frame meant the button should be pressed; a yellow one meant it should not. (This is referred to as a Go/No-go experiment.) Those patients with higher levels of anger made more mistakes, especially when the pictures depicted hostility, which made their impulse to press the button, regardless of the colour of the frame, even stronger. Impulsivity was worsened by emotional context, creating the conditions for anger contagion and chaos, as heightened emotions were compounded by lower accuracy of judgement and spiralled out of control. The real-world consequences of this tendency are plain to see, throughout history, across the globe and (on a smaller scale) in our own lives.

The way we relate to uncertainty will determine whether we face it with curiosity or try to avoid or flee from it. Such reactions can mean the difference between anxiety and excitement for an individual and between hostility and collaboration for a group. Learning to tolerate uncertainty should be a high priority for both the individual and the group as we seek to project a mindset based on curiosity about other people's points of view.

Wherever and whenever you can choose who to spend time with, steer towards those who display open-mindedness about their own lives, other people and events taking place in the world. Seek out those who tend to look on the bright side rather than always seeing problems and obstacles. Listen to advice from people with different experiences and remember that you can file the stories of Pollyanna-ish optimists under planning for best-case scenarios and those of doomsayers under preparing for worst-case ones. This is all potentially useful information when you're next facing a situation of uncertainty, but as for the day to day, stick with the curious rather than the fearful. And try to ensure that what *you* are transmitting to the group reflects the base assumption that uncertainty can be an invitation to discovery and positive change, rather than always and necessarily a threat.

Mark Gallagher, the Formula One executive I met at the conference on corporate resilience, closed his speech by reminding us that change typically feels threatening at the time, even if in the long run it will be judged to have been necessary and positive. 'When Michael Schumacher was winning the world championship, he was sponsored by Marlboro. Then all the tobacco sponsorship got banned. When I look back, I think to myself how embarrassing that our whole industry was predicated on promoting smoking. The ban forced us to realize that we weren't in the advertising

business; we were in the technology sector. Over the last twenty years, Formula One teams have recognized that our core capability is in creating high-end technology solutions in automotive, aerospace, renewables and defence. Red Bull, Mercedes and Ferrari now know that racing on Sunday is the shop window for us to sell technology solutions to industry from Monday to Friday. We still have sponsorship in Formula One, often from engineering firms such as Oracle, but today it's only about 22 per cent of our revenue, whereas thirty years ago it was 90 per cent and it was from sectors like tobacco. Ultimately, you have to be prepared to *adapt*.'

Mark also talked about the crucial capacity to distinguish between what you can control – and deal with it – and what you can't control, and flex with that. 'Every three to four years, there will be an event outside of Formula One that poses a major challenge. Could be a new piece of legislation like the tobacco ban, an economic crash in a key market; could even be a pandemic. We have to accept that these things will happen and that our strategies will become heavily compromised by things outside our control. That makes the inherent ability to adapt, to reinvent, to create, to play to our core strengths, essential.'

His words made me think of those poor students struggling to solve an unsolvable puzzle in the experiment they had been set up to fail, and of myself when I was a 27-year-old post-doc student realizing that any sense of certainty about my career had just been wiped out. Uncertainty is an inevitable by-product of change, which is an inevitable feature of life. Sometimes events are responsive to our actions; sometimes they're not. In any situation, but especially a fast-moving or high-stakes one where uncertainty is likely to bite hard, the smartest responses are those that will allow us to test, explore, persist and pivot as necessary, sustained by a belief that we will do what we can to adapt.

## **|EXERCISES|**

A brain fit for the 21st century is ... able to tolerate  
uncertainty and ambiguity

- Do thirty minutes of fairly intense physical exercise every day to boost your hippocampal health. A flourishing hippocampus helps to inhibit an

overactive stress response in your brain and body, providing more resilience. It might also be linked to greater imaginative abilities too, so that you can conjure up a better future when faced with change.

- When feeling overwhelmed by ambiguity or the prospect of change, pause for a few minutes and do some simple breathwork. Breathe in for five seconds through your nose, hold your breath for five seconds, exhale slowly for five seconds through your mouth, and pause for a final five seconds. Repeat the process ten times. This helps us to regulate the hypothalamic-pituitary-adrenal (HPA) axis, which is crucial for your body's stress management, so that we do not enter a distressed state; it helps us to think less reactively and engages the anterior cingulate cortex region of the brain for longer-term problem-solving.
- Use your honed powers of imagination to run through possible ways in which a particular situation might pan out. Prepare for both the best- and worst-case scenario. Create a 'paradise' and 'doom' map using Post-It notes to identify where the main risks and potential problems lie and work through how they could be addressed if they ever do arise. Visualizing these two extreme outcomes, and your reactions to them, can help with your decision-making and boost your confidence in dealing with such issues in the future.

## Thinking with Clarity and Precision

TOWARDS THE END OF MY PHD, I was struggling to focus, think or work. My funding was running out and the deadline for delivering my thesis was looming. I told myself I just needed to stop procrastinating, sit down and get the job done, but weeks rolled by and still I wasn't making progress. I couldn't focus enough to think clearly about what I needed to write, and this inability was becoming distressing. A college friend recommended ADHD medication and told me where I could get some on the black market. I didn't opt for that. Instead, one drizzly cold Fenlands Friday, I visited my GP to discuss the issues. She was German, very stereotypically so. She listened to me. Then, in a very straightforward and direct manner, she asked if I was likely to commit suicide that weekend due to the stress. I replied no, that was very unlikely. She commented that she also got that impression. Then she suggested I drop the problematic boyfriend I'd mentioned, get back into daily exercise, eat healthily and change my routine to minimize all distractions so that I could focus on the task in hand.

Exceptional advice. I duly emailed my friends to say I would be uncontactable for the next few months, but that I would resurface when I'd finished my thesis and looked forward to catching up. I broke up with my boyfriend. I got back into running, started eating a bit more healthily and changed my routine to join two other PhD students in the college library for the nighttime shift. We worked together, holding each other accountable and providing support, every night until 3 a.m., making the most of the quiet, distraction-free time when everyone else was asleep. For three months I lived a very focused life so that I could think clearly enough to complete the job. It worked. I passed my final PhD viva exam with exceptionally minor corrections. I still go running, eat healthily and am prone to ditching problematic boyfriends and other distractions as required.

I'm also writing this chapter at 5 a.m. while everyone else is asleep and the world seems quiet.

None of what my doctor recommended was new knowledge, but the combination of her clarity and her calm sympathy was exactly what I needed. She offered sound practical advice about how to change my environment to optimize it for clear thinking. Her emotional intelligence was measured and effective. Rather than admonishing me by implying I needed to pull my socks up, she listened to me and asked my opinion. This allowed me to regulate my mounting feelings of stress, which in turn boosted my clarity of thought and sense of agency. I'd say my GP's advice for how to focus, think clearly and work precisely has held up brilliantly in the intervening years.

Who wouldn't want to think more clearly? Clarity and precision of thought are evidently preferable to thinking foggily or imprecisely, in this century or any other. So there's an irony in acknowledging that it really isn't clear what we mean by clear thinking, except in relation to its opposite. Though perhaps this isn't surprising, given that, as we've seen throughout the book, the brain makes endless trade-offs between different regions, their associated skills and the behaviours they give rise to, in order to steer us successfully through the world. It is constantly seeking balance, and clarity can only ever be partial and temporary. We know clear and precise thinking when we see it, though, especially when it stands out against muddle or confusion.

Usually, the most intelligent strategy for any individual to adopt to keep all the cognitive plates spinning (where such strategizing is in fact under your conscious control) is to aim for a sweet spot: not too much fast thinking because it risks descending into shortcut and bias; not too much slow thinking because it risks missing an insight or opportunity. Not too much precise thinking because it can become formulaic and laboured; not too much obsession with novelty because it can tip into risky behaviour. That median point may not sound exciting but it's an intelligent goal in terms of cognition. The brain's sweet spot is where we can reap the most benefits from the widest range of cognitive skills and avoid the greatest number of pitfalls. It's the space that affords each of us the maximum liberty to operate and discover what we can do.

Using this model to think about clear thinking, I see a number of ways to define it. To think clearly is to be able to focus on a problem, but also to be

able to avoid getting hyper-focused on any *one* problem. To think clearly is to be able to sustain attention and then refocus when required. It means being able to flex your memory and banish brain fog. Dial down mood swings so that your thinking isn't thrown into confusion by sudden emotional surges. Push your thinking harder so that you feel confident that you are being as clear as possible. Know what you think, without losing sight of other people's points of view.

Some of these skills have been touched on in previous chapters. That's not surprising since no strand of cognitive competence can be neatly separated from any other. Intelligence is a whole-brain activity, and brain regions connect with each other to produce highly sophisticated interactions. Clear thinking is a refined skill built up from many different activities. So, for example, much of what we know about emotional intelligence and regulation, perception and bias, and thinking long-term versus in the moment, is pertinent to understanding what underpins clear thinking and what we can do to make the most of it.

I'll also be drawing on cutting-edge neuroscientific research into food as brain fuel, the gut-brain axis and the impact of diet on brain health. Recently published and ongoing projects have demonstrated thrilling potential to drive breakthroughs in clear thinking, even for people who suffer from conditions that involve chaotic thinking, such as schizophrenia and bipolar disorder. Clarity of thought is intimately associated with a healthy brain: you need only think of the tragic confusion endured by dementia sufferers to grasp how essential it is, so it's no surprise that in this chapter much of our focus will be on interventions that boost health, mainly through diet.

## How to focus, but not be myopic

We are living in an age of anxiety about our inability to focus. Many of us have a nagging sense that our focus has been 'stolen<sup>[1](#)</sup>', as journalist Johann Hari puts it, by internet-enabled technology and that we're losing an essential ability to choose where we direct our attention and how to sustain it. We no longer read novels; we doomscroll. We scan headlines or listicles rather than read long-form journalism. We don't read at all; we watch TikTok videos and flit from fragment to fragment of visual data. We're losing critical thinking and empathy along the way, and the consequences



for democracy and tackling existential challenges are grievous. In his book *Stolen Focus*, Hari lays out the case for the prosecution: surveillance capitalism, as carried out by the social-media giants, is largely responsible. It's a compelling narrative that has become enshrined as a virtual truth, but it's not the only story. It's not that I disagree with much of the analysis, more the weight he gives it.

There's no doubt that we are overwhelmed by data as never before, and our brains are struggling to cope. As we saw in the previous chapter, managing incoming data has always been a difficult job that the brain must perform in a flawed way just to do it all. That task has been made much harder by our exposure to 24-hour news and the never-ending scroll function on our handheld devices. Suggestions for how to cope abound and there has been an avalanche of advice. We are directed to use tools such as mindfulness meditation, switch off notifications from apps and add strict no-interruption times to our work calendar. I find a lot of this personally helpful. You already know I'm a fan of mind-clearing physical exercise before I start work. A tidy desk once I sit down and the 'Do Not Disturb' function enabled on all my devices are essential for me to be able to think clearly.

And yet, as Hari partially acknowledges in his book, the data does not support the simple portrayal of big tech as the undisputed villain of the piece. I happen to think these companies might be villainous for all sorts of reasons, but it's important to admit that there isn't yet much quality long-term data on the impacts of social-media usage, and what there is from my own discipline suggests a more nuanced conclusion than the one Hari draws.

In March 2022, a team led by Dr Amy Orben,<sup>2</sup> of the University of Cambridge, and Rogier Kievit, Professor of Developmental Neuroscience at Radboud University Medical Centre in the Netherlands, published the results of a study that highlighted how a 'one model fits all' approach simply does not apply in this area. They were looking at the relationship between mental health in adolescents and their use of social media, and found interesting variations between different groups, and huge variation between individuals. They observed specific windows of developmental sensitivity that are different for girls and boys, for example, with girls who use social media heavily between the ages of eleven and thirteen reporting lower life satisfaction a year later, while for boys the critical window seems

to be between the ages of fourteen and fifteen. In both sexes, increased social media use at the age of nineteen again predicted lower life satisfaction a year later. At other times during adolescence the link was not statistically significant. Lower life satisfaction was also itself a predictor of heavier social-media use.

All the scientists involved called for more research. Professor Andrew Przybylski of the Oxford Internet Institute at the University of Oxford pointed out that this would rely on tech companies sharing data with independent scientists, something that they have often been reluctant to do. As he says: ‘To pinpoint which individuals might be influenced by social media<sup>3</sup>, more research is needed that combines objective behavioural data with biological and cognitive measurements of development. We therefore call on social-media companies and other online platforms to do more to share their data, and, if they are unwilling, for governments to show they are serious about tackling online harms by introducing legislation to compel these companies to be more open.’

It’s not that the scientists were saying there was no link between smartphones, social media and distressed teens, more that causality is hard to prove, given that this group is going through the huge biological and social changes associated with adolescence. And while there seemed to be negative consequences for many, for others there were associated benefits. As Professor Kievit commented: ‘... not every young person is going to experience<sup>4</sup> a negative impact on their wellbeing from social media use. For some, it will often have a positive impact. Some might use social media ... because they don’t have anyone to talk to about a particular problem or how they feel – for these individuals, social media can provide valuable support.’

In January 2025, the UK government commissioned further research,<sup>5</sup> led by Cambridge University’s Dr Orben in collaboration with researchers from other leading UK universities. This work will assess the data on causality, especially over shorter time periods, in the face of what Orben has described as ‘huge concern about the impact of smartphone use<sup>6</sup> on children’s health. This is a complex and rapidly evolving issue, with both potential harms and benefits. Technology is changing by the day, and scientific evidence creation needs to evolve and innovate to keep up.’ The work is under way and hopefully the first wave of results will be made

available by 2028. In the meantime, while Dr Orben emphasizes that her job is to examine and present evidence, not make policy, her work does advocate for the right of children to have access to phone-free space and time, and makes it clear that, for some vulnerable children, the risks of over-exposure to smartphones and social media are real.

Johann Hari discusses other causes of diminished focus in his book, including obesity, poor diet and exposure to air pollution, and while he gives them less attention than tech, he's right to flag these issues. To my mind they contribute a great deal, and when we overlook them, we're missing the chance to use them as levers for positive change. Diet, above all, is relatively easy for an individual to control and can yield incredible benefits, as we will see.

While there's no doubt that endless interruptions degrade our capacity for sustained attention, it's neither possible nor desirable to create an environment in which distractions have been eliminated. Besides which, deep concentration is only sustainable over long periods when it's happening in a pleasurable flow state, and even then, it's cognitively and metabolically demanding. Brain work is hard and your brain needs periods of rest to return to focus, learn or have new ideas. Rest for the brain doesn't mean staring at a different screen or focusing on a different task; it means a change of pace and a decrease in stimulus. One of the key ways to rest your brain is to let your mind wander, which, as we saw in the earlier chapter on creativity, is not the opposite of focus so much as its complement, enabling creativity and innovation to emerge.

So while I share some concerns about our twenty-first-century capacity to pay attention, I don't think it's quite the catastrophe it's often made out to be. Nor do I think it's intelligent to aim for some unattainable goal of optimum focus over a whole working day. The fact that our brains get tired does not have to be a disastrous disadvantage if we work with the cycles of energy intelligently, knowing that over the medium and long term, resting periods will be just as productive, creative and rewarding as focused ones. Optimizing our energy levels by consuming the best fuel, resting periodically and not stinting on sleep will unlock far greater cognitive benefits than endlessly searching for productivity hacks.

## What do you really think?

Making meaning from the chaos of incoming data depends on identifying patterns and developing an overarching story that our mind can use to instigate responses. Whether we are trying to focus on a conversation with a colleague in a bustling restaurant or struggling to work while blocking out the hum of the heater and the shaft of sunlight breaking through the clouds, our brain must filter out distractions, focus on salient information and construct meaning so that we can take the action that is most favourable for our future selves. Every task depends on this filtering and analytical process but the more complex the task, the more iterations you're going to need.

Neuroscientists have for years been interested in exactly how the brain enables us to perform this feat of paying attention in a way that allows analysis to take place. For decades they zoomed their studies in on the cortex, supposing it to be the key brain region involved. The cortex underpins general fluid intelligence and executive function, they reasoned, so surely it's at the crux of this important neurological work too? In 1984, Francis Crick, having won a Nobel Prize for helping to elucidate the structure of DNA, turned his research brain to the thorny question of consciousness. He proposed that the thalamus – an evolutionarily ancient, conserved region deep in the brain that had previously been overlooked – controlled attention<sup>7</sup>. His suggestion was that it acted as a gatekeeper for consciousness, filtering and discarding irrelevant information to allow one to focus on what was important.

Dr Michael Halassa of New York University<sup>8</sup> and Professor Karl Diesseroth of Stanford University in California were interested in this idea and, after much experimental delving into mice, found there was indeed a thin layer of stop-signal neurons known as the thalamic reticular nucleus (TRN) that surrounded the thalamus like a protective shell and which worked like a coarse sieve for consciousness. These nerve cells let sensory inputs through when an animal was awake and attentive to something in its environment, but inhibited them when the animal was asleep. Halassa and colleagues then did a clever series of experiments to demonstrate that when a mouse was presented with different stimuli – audio and visual information – and had to follow these cues in order to get rewards, its brain would turn the TRN into a sort of cerebral and emotional DJ, tuning the knobs to dial down information that wasn't relevant so the mouse's prefrontal cortex would not get distracted. If the mouse needed to prioritize auditory signals, for example, the prefrontal cortex told the TRN to inhibit the visual

thalamus, stripping away irrelevant data. Previously, neuroscience had preferred the metaphor of an attentional searchlight to explain its hypothesis about how the brain made meaning by shining a light on key information in turn. This was, in fact, correct but backwards: the brain wasn't training a light on stimuli of interest; it was dimming the light on everything else so that the bits of data that the brain perceived as meaningful stood out.

The team then discovered an additional step in the process. Located close to the TRN, the basal ganglia – a set of regions deep in the brain involved in learning, reward, habit formation and the regulation of movement – pass on messages from the prefrontal cortex to inhibit signals in a much more finely tuned way. This allows the mouse to exclude not only the unwanted visual signals but also *different types* of auditory signals, so that focus can be trained on a specific tone. This simple circuit linking the cortex, basal ganglia and thalamus seems to allow a much more precise dampening down of irrelevant information, so that the executive functioning, learning, habit-forming and movement-directing regions of the brain can act appropriately to enable focused, clear interaction with and interpretation of the world around us. This all links with our behaviour: perception, reward, learning, habits and actions are inextricably intertwined.

Knowing more about this delicate interplay helps me to understand a little more about my own, often baffling behaviour and that of my family and friends. I can then tweak the meanings I make about my interactions with the world. If I'm struggling to get a job done, for example, I take a deep breath and ask what factors are under my control and how I can minimize negative impacts. I try not to overload my TRN with too many inhibiting duties, by reducing extraneous incoming information. Playing to the basal ganglia and the cortex, I will make bullet-point lists of priority tasks and reward myself when they have been completed or when an allotted period of concentrated time has passed. I remind myself of the point and the value of whatever job I'm doing. I think about who might benefit from it and why I'm completing it.

I also appreciate that this attentional brain circuit is a simple, very dedicated one. If it's going to play its part in allowing my brain to work optimally for clear and refined thought, it would be good to give it a rest from time to time so that other ways of thinking can take over. This is how the process of refining our attention, detecting patterns and creating stories to explain them builds meaning from raw data. I ensure I create space in my

day for mind-wandering, so my brain can be happily at rest, moving from subject to subject with no focus. My mind-wandering usually takes place during physical exercise, so I start the day with a run, swim or cycle and break up my work by doing errands on the bike or going for a walk. I almost always find that I know more clearly what I think about a remark my friend made or an article I've read at the end of such a sequence of focus and release.

## Protect your memory and banish the brain fog

There's accumulating evidence that the number one thing we can do to support clear thinking is feed our brain towards it. Certain foods, especially those based on refined carbs, saturated fats and sugar, can cause a state colloquially called 'brain fog'. You've no doubt experienced it yourself at some point, perhaps after eating a particularly heavy meal or if you've been on holiday and overindulged on all fronts. Trying to get your brain back on track can be tricky, and there's sound neuroscientific reason behind this.

The highly processed foods that we increasingly rely on in developed countries are crammed with saturated fat and refined sugar, which makes them not only palatable but also toxic. These foods include, for example, various products currently hiding in shame in my fridge and kitchen cupboards – shop-bought pizza and salad dressings, cakes, breakfast cereal and biscuits. Their combination of high fat and high sugar has been shown to contribute to significant problems with memory and learning. And of course, clear thinking becomes infinitely harder if you can't recall key information or update your knowledge with new data.

Over the last hundred years, our average blood-sugar levels have massively increased as we have consumed more processed foods with a high glycaemic load. There is now a global epidemic of type 2 diabetes, prevalence of which has tripled in the last two decades.<sup>9</sup> Diabetes, in addition to all its other associated problems, is an early risk factor for later-life dementia,<sup>10</sup> as numerous long-term cohort studies have shown. The UK's Stress and Health (or Whitehall II) study was launched in 1985 and has been following the health outcomes of over 10,300 London-based civil servants<sup>11</sup> ever since. Those with diabetes were found to have experienced a faster decline of 45 per cent in memory, 29 per cent in reasoning and 24

per cent in overall cognitive score than those without the condition. Similar results were found in studies from Israel<sup>12</sup> and the United States.<sup>13</sup> The correlation between diet and cognition in the elderly is so strong that researchers have been able to accurately predict poorer memory and information-processing scores<sup>14</sup> from an initial questionnaire about the person's diet twelve years previously.

The typical Western diet is of course also bad for our waistlines, and long-term significant obesity is associated with diminished cognitive performance across a wide spectrum<sup>15</sup> of skills, including verbal and stimulus-reward learning, working memory<sup>16</sup> and executive functions<sup>17</sup> such as adaptation to novel situations, cognitive flexibility, attention span, planning and judgement. Over the long term, severe obesity is associated with profound changes to the brain<sup>18</sup> – nerve cell death and atrophy of crucial areas, including the hippocampus and prefrontal cortex. Damage to these regions not only impairs the cognitive functions of learning and memory but also prevents the reception of satiety signals<sup>19</sup> that tell us we are full and should stop eating. The double whammy of a diet that's heavy in processed high-calorie, low-nutrient foods leads directly to weight gain, lower cognitive function and increased risk of dementia. This amplification loop diminishes our ability to think clearly about everything from food choices to everyday tasks.

Scientists have in the past been (rightly) cautious about attributing causality to specific foods. It's hard to make definitive pronouncements about impact when timescales are long and there are so many variables in play. As long-term studies have piled up, that caution has been replaced by a willingness to say that, in general, a diet high in sugar and saturated fat tends to be bad for people. This willingness has also been bolstered by research into the impacts of these foods over much shorter timescales, and in young healthy people as well as the elderly and unwell. In one study, 102 students from Macquarie University, Sydney, were fed either a breakfast high in saturated fat and added sugar (the Experimental group) or one of similar palatability and food types but significantly lower in saturated fat and added sugar (the Control group). The two groups consumed a toasted sandwich and chocolate milkshake, but Experimental group's toastie was made with white bread, bacon rashers, cheese slices and spreadable butter, their milkshake with full-cream milk, ice cream and chocolate biscuits, and



they had chocolate for a snack. The Control breakfast toastie, on the other hand, was made with wholemeal bread, ham, low-fat cheese slices and avocado spread, their milkshake from banana, chocolate-flavoured whey protein isolate and water, while their snack consisted of roasted almonds. Participants were randomly assigned to a group by order of arrival to the experiment, and they followed this regime for either four<sup>20</sup> or eight days.<sup>21</sup> Those eating the Experimental breakfast consumed significantly more calories, total fat, including saturated fat, total carbohydrates and sugar, but less protein, than those eating the Control breakfast. The group who had eaten the Experimental breakfast experienced a decline in memory, but the most marked change was a diminished ability to read their own bodies for information: even when they were full, food still looked delicious. Their bodily state was no longer inhibiting retrieval of pleasant food-related memories.

The various studies that have confirmed a virtually immediate negative impact from eating these foods have shown that we're not dealing with correlation. It isn't the case that people who are biologically programmed to prefer certain highly palatable foods<sup>22</sup> are also more likely to have issues thinking clearly. Even a healthy, lean young person eating a typical Western diet<sup>23</sup> will very quickly show cognitive decline, struggle to think clearly and eventually exhibit brain changes reminiscent of injury. The detrimental effects of these foods on the brain really cannot be overstated.

What are the mechanisms underlying this? Professor Rut Fadó and her colleagues at the International University of Catalonia in Barcelona wanted to understand how impaired thinking might be related to altered brain anatomy. They recently published a review of research in rodent animal models<sup>24</sup> (mice, rats and guinea pigs), which showed that just five days of a high-sugar, high-fat diet was, in line with the human data, enough to significantly reduce capacity for learning and remembering. Rut and her team observed that the rodents' brains were showing reduced nerve cell branching, which meant a diminished potential for connectivity between cells, as well as changes to the shape and size of the synapse (or gap between brain cells), which meant information transfer was altered. Receptors trafficking across the synapse were affected, specifically AMPAR ( $\alpha$ -amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid receptor), which facilitates rapid communication between neurons and is

associated with memory formation and recall. In some studies there were also decreased levels of BDNF (brain-derived neurotrophic factor) in the rodents' brains. This is a lovely chemical that bathes the brain and protects neurons and synapses, encouraging healthy nerve growth. The overall impact of all these anatomical and chemical changes was a reduction of connectivity across brain circuits and between regions. Turning new learning into memory and then being able to recall and integrate new memories were all affected. Poor diet meant that the brains were unable to flourish, both anatomically and behaviourally.

If you're male, or have passed through the menopause, the negative effects of a poor diet are particularly problematic. Scientists have observed that, in mice at least,<sup>25</sup> testosterone appears to exacerbate the detrimental impact on the brain of food that is high in sugar and fat, whereas oestrogen offers some degree of protection against it. This has obvious implications for boys and men and might also explain why the perimenopause is associated with symptoms of brain fog. (As a woman in my mid-forties, I'm ramping up my intake of oestrogen-mimicking chemicals by increasing the soya, tofu and broccoli in my diet and being particularly careful about minimizing the amount of processed foods I eat.)

If all this is making you think twice about that sausage roll and glazed doughnut you were looking forward to eating at lunch, I can only approve. We all need to massively reduce our intake of such foods, not only to lower the risk of diabetes and cardiovascular disease but also to maximize our chances of avoiding dementia and preserving brain health.

The good news is that the most recent evidence suggests dietary fat is not in itself an issue, especially polyunsaturated fats derived from seeds, nuts, fruits like coconut and avocado, and fish. The Mediterranean diet, rich in all these fats, is great for our brains.<sup>26</sup> That's because while 73 per cent of the brain is made of water, about 60 per cent of the brain's dry weight is fat. A healthy brain is full of omega-3 fatty acids, for example, which help to protect nerve cells, acting as a fatty insulating layer that wraps around the neurons' axon structure so that electrical signals can be sent zipping across the brain at high speed and with high integrity. They are also essential for new neurons to be built and new connections between cells to form. Rut's report into diet and cognition drew the obvious conclusions: 'At the molecular level, the Mediterranean Diet<sup>27</sup>, with high omega-3 content

(present in fish, seafood, soybean oil, nuts, and seeds), blocks synaptic damage linked to aging and neurodegeneration and slows cognitive decline.’ A high intake of omega-3-rich foods, as well as green vegetables, berries, nuts and seeds, will deliver micronutrients such as vitamin B12, iron and zinc, which have also been directly linked to improved cognition and a lower likelihood of developing dementia.

It’s never too soon to boost our consumption of these foods. Children and adolescents will benefit hugely and over a relatively short time, as well as establishing healthy eating habits that will support long-term brain health.

Researchers from the University of Bristol recently published<sup>28</sup> their work on the impact on children’s development of eating fish and seafood, for example, which found benefits for sociability as well as clarity of thought. They used questionnaire data from 5,969 of the participants in the ‘Children of the 90s’, a birth-cohort study conducted on 14,500 children born between 1991 and 1992, and have just received funding to continue their pioneering longitudinal research. The data was collected over a period of two years and adjusted for known social and demographic factors (including the child’s ethnic group and sex, and age at IQ testing; maternal age, education, prenatal smoking status and alcohol consumption, family adversity index, length of gestation, birthweight and breastfeeding duration, etc.).

The main finding is that children who consumed the least amounts of seafood at the age of seven were likely to be less ‘prosocial’ aged seven and nine than those who regularly consumed seafood. (‘Prosocial’ behaviour includes friendly interactions, altruism and sharing.) They were also more likely to have peer problems and exhibit hyperactivity. The NHS currently recommends that children should eat at least two portions of fish per week, with one of these being an oily fish such as salmon or mackerel.

If you’re wondering whether it’s ever *too late* to make these changes, I would simply say that sooner really is better and offer some encouraging news for those of you who, like me, love cheese and red meat. It seems that omega-3 fatty acids can reverse most of the negative molecular impacts of saturated fats in the brain. This means that, as long as we reduce our consumption of foods high in saturated fats (cheese, butter, meat, etc.) and eat plenty of foods rich in unsaturated fats (vegetable oils, fish, seeds, etc.), our diet probably won’t harm our cognitive health.

Staying hydrated is just as important for clear thinking as eating the right foods. Even mild dehydration is associated with impairment in cognitive

performance,<sup>29</sup> attentiveness, short-term memory, judgement and decision-making. Hardly surprising since, as we saw, the brain is 73 per cent water. It's reported that losing just 2 per cent of this<sup>30</sup> (which happens when we are mildly dehydrated) can create a profound state of brain fog. Generally, most people require 2–3 litres of water a day, though this varies depending on humidity levels, the amount of exercise you take and how much salt is in your diet. (The Western diet is high in salt as well as fat and sugar, compounding its deleterious effect.) Alcohol is massively dehydrating for hours after you've consumed it, and sugary drinks disrupt cognitive function and satiety awareness. The best way to make sure you are hydrated enough to think clearly is to drink plenty of water and keep an eye on the colour of your pee. If it's pale yellow, verging on clear, your brain is getting all the hydration it needs.

And if you're wondering, 'Hang on a second – what about sleep? Surely sleep is the number one thing we need for clear thinking?', I would agree that it's crucial. Being really tired is probably the most familiar form of brain fog for most of us, and it makes clear thinking all but impossible. As anyone who has ever worked night shifts, cared for a baby or even just grappled with a few nights of insomnia will know, the impacts of sleep deprivation on cognition and mood are unpleasant in the short term and devastating in the medium-to-long term. Studies have shown that insufficient sleep<sup>31</sup> leads to a general slowing of response speed and greater variability in performance. A single night of total sleep deprivation<sup>32</sup> triples the number of lapses in attention and impairs our ability to placekeep (perform a task involving multiple sequential steps without repeating or skipping steps). Gentler studies (reducing sleep from eight to four hours a night)<sup>33</sup> also resulted in immediate reductions in vigilant attention, doubling attention lapses after just one day and increasing them eight-fold after fourteen days. In the longer term, being chronically sleep-deprived is associated with an increased mortality risk.<sup>34</sup> While many of us suspect we need less sleep as we age, studies show that seven to eight hours a day is optimal<sup>35</sup> for the majority of middle-aged and older adults.

So, yes, sleep is important for clear thinking, not to mention our health more generally. But recent data indicates that it's the more creative,

divergent and innovative aspects of cognition, alongside our emotional awareness, that appear to be most significantly degraded by lack of sleep. This is interesting in the light of what we saw back in [Chapter 2](#) about a sweet spot for maximum creativity being the N1 stage of our sleep cycle, poised between wakefulness and dreaming. It seems that sleep is central in the neural processing that supports creativity and emotional intelligence.

Sleep is another of those boom subjects for neuroscientists,<sup>[36](#)</sup> and the exciting research into it over the last decade has been popularized in books such as *Why We Sleep* by Matthew Walker. While the subject is important, I sometimes wonder whether society's anxious obsession with getting enough sleep is counter-productive. There is more on sleep in the next chapter, but for now I will confine myself to making the connection between sleep and diet. Guess what is proven to impair our ability to sleep? You got it – our ultra-processed Western diets. One small example: have you ever found yourself awake and starving at three in the morning, perhaps hovering in front of the fridge, after a day of bingeing on low-nutrient, sugar-filled, easy-to-eat foods? Studies carried out by Professor Denis Burdakov and colleagues<sup>[37](#)</sup> at the universities of Cambridge and Zurich suggest that this might be your body sending SOS signals to your brain to make you wake up and go in search of essential nutrients. Although their studies were conducted on mice, this mechanism is probably rooted in evolutionary history and may well translate to humans. Their conclusion was that if an animal has not absorbed enough essential amino acids, a signal will be sent by the brain to promote the urge to go in search of other sources of food. Since I read Denis's study, I now load up on essential amino acids in the form of eggs, chicken, fish, soya or quinoa before I go to bed, especially if I know I have a big day coming up and a good night's sleep is crucial.

## Better mood, clearer thoughts

Our mood will profoundly affect our ability to think clearly, in the moment most obviously, but also long term. Emotions, it bears repeating, provide useful information and repressing them is highly ineffective, but managing them is essential. If we can't steer our mind back to a state that isn't dominated by anger, irritation, fear or melancholy, we're going to struggle to think clearly, make good decisions, find solutions or learn from our

mistakes. Learning how to regulate your emotions as they arise, as well as how to observe and question them in hindsight, is perhaps the single most crucial skill you can cultivate for a flourishing brain. (If you need to flip back to [Chapter 1](#) for a reminder on the science and the solutions, please do.)

Once you've made a behaviour-based plan for working *with* your feelings rather than against them, your next intervention to dial down your moods and allow space for clarity of thought is, again, diet-based. Luckily, the foods that reduce brain fog and risk of dementia also have a protective effect against low mood and depressive symptoms. Increased consumption of omega-3 fats is a highly effective way to protect against mood disorders. While they won't be a miracle intervention for every individual, a recent meta-analysis of twenty-six studies with 2,160 participants<sup>38</sup> showed an overall beneficial effect of omega-3 polyunsaturated fatty acids in safeguarding against depressive symptoms.

At least as important to our mood and thinking as the nutrients we put into our bodies are the microbes that live in our guts and feed on the food we eat. The gut microbiome is made up of bacteria that take up residence before we're even born, transferred from our mother's microbiome via the placenta and amniotic fluid. They populate our body further at birth, and continue to diversify as we eat different foods and interact with our environment.

The gut microbiome, and more broadly the concept of a gut-brain axis, has received a huge amount of attention from scientists in recent years. There is now compelling evidence that our brain and gut are intimately connected, mutually influencing each other, and share responsibility for shaping our cognitive and emotional state. Scientists have been aware of the link for at least two hundred years, since pioneering studies that demonstrated that digestion is much slower<sup>39</sup> when we're angry or irritable. (Pioneering and ethically dubious, as Matt Warren and Miriam Frankel discuss in their book, *Are You Thinking Clearly? 29 Reasons You Aren't, and What to Do About It*. They recount the observations made by a US army surgeon called William Beaumont between 1822 and 1833 of how mood influences digestion. He was literally watching what was going on in the guts of an unfortunate man called Alexis St Martin, who had survived a gunshot wound to the stomach that left his innards exposed via a fistula. Beaumont took him in, conducted 238 experiments on him and exhibited



him to the public. When Alexis was angry – which must have been quite frequently, one would imagine – food took far longer to pass out of his stomach and into his colon.)

We now know that mood affects digestion, food affects mood and mood affects thinking in a complex interplay of cause and effect that is increasingly well understood. At the core of these dynamics are the gut microbiome and the vagus nerve, a bundle of nerves that, as we saw in [Chapter 1](#), connects gut to brain via the peripheral nervous system and allows for the transfer of information and alterations to brain chemistry in response to changes in the environment.

Having insufficient ‘good’ microbes to support a healthy digestive system has been shown to have a serious impact on mood and thinking. Brain fog and low mood are the result. Experiments on so-called ‘germ-free’ rats and mice<sup>40</sup> (those reared in sterile conditions or given large doses of antibiotics that reduce their gut bugs to a minimum) have shown that they are more likely to be anxious, hyperactive, prone to risky behaviour and less willing to socialize.<sup>41</sup> They also have reduced ability to learn and remember. The study’s authors suggest that the antibiotics strip away even healthy microbes in the body, leading to alterations in the immune system and to the way that neurons develop, as well as changes to activity in the vagus nerve.

Similar results have been observed in humans whose gut microbiome has been compromised by antibiotic use. A study carried out between 2014 and 2018<sup>42</sup> monitored 14,542 nurses working for the NHS in the UK. The nurses were separated into two groups: those who had used antibiotics for long periods of time (more than two months) and those who had not. The researchers were interested in whether antibiotic use would have an impact on cognition. They discovered that it did. Those who had taken antibiotics scored significantly lower on tests for learning, working memory and attention-based tasks when compared with those who hadn’t. This may not sound surprising – whenever I feel ill, especially if I am ill enough to need antibiotics, my thinking certainly feels off-kilter. But strikingly, the negative impact was measurable *up to seven years after* the use of medication. Long after they had recovered, the nurses who had taken antibiotics had slightly poorer cognition. In fact, the study’s authors estimated that two months of antibiotic use was equivalent to the cognitive decline scientists would



expect in three to four years of ageing. Their hypothesis was that stripping away microbes from the gut had a measurable impact on cognitive ability even years later.

Given the incredible dedication and professionalism exhibited by medical personnel who are constantly exposed to pathogens, and the obvious fact that we would rather not have our treatment in the hands of cognitively impaired staff, perhaps some simple steps might be taken? The hospital canteen could provide clarity-boosting meals filled with gut-microbe-friendly ingredients. Health visitors, midwives and GPs could be prescribed pre- and probiotics, free of charge.

There is a lot of marketing buzz around food supplements but the evidence for prebiotics and probiotics is solid and increasing all the time. Probiotics are the good bacteria that add variety and resilience to our gut microbiome. You can boost your probiotic intake through diet, by eating a wide variety of plant-based foods, or you can take a supplement. Prebiotics are foods that help the good bacteria in our gut to thrive. They include fermented foods, such as kimchi and kefir, and fibrous vegetables like cabbage, peas or asparagus.

One recent review of human studies examined thirty experimental papers<sup>43</sup> investigating the impact of taking probiotics across a variety of ages, populations and cognitive skills. Probiotic use seems to enhance cognitive function and slow cognitive decline. In a study of Alzheimer's patients who drank milk<sup>44</sup> supplemented with four species of probiotic bacteria for twelve weeks, they scored better on a test to measure cognitive impairment compared with those who drank regular milk. Healthy individuals who ate yoghurt containing a mixture of probiotics<sup>45</sup> twice a day for four weeks had reduced emotional brain activity when exposed to images of angry and frightened faces compared to people in a control group. In a more recent study,<sup>46</sup> those who were put on a diet that included a lot of fibre, prebiotics and fermented food (such as onions, yoghurt, kefir and sauerkraut) for four weeks, reported feeling less stressed than those in a control group. Prebiotics have been shown to have some impact in people with extremely disorganized and chaotic thinking<sup>47</sup> who have been diagnosed with conditions like schizophrenia and bipolar disorder. Amy Chia-Ching Kao and Philip Burnet from Oxford University have recently explored using prebiotics to alleviate psychosis and help patients to think

more clearly. ‘We found that giving a prebiotic to people with psychosis<sup>48</sup> did improve cognitive function according to the clinical scales,’ reported Burnet.

## Bioenergetics for long-term clarity of thought

We’ve seen how the actions of the gut–brain axis can have a profound impact on our ability to focus and sustain attention, regulate our emotions and to occupy the cognitive sweet spot that allows for maximum clarity of thinking. I now want to delve into a fascinating new area of research called ‘brain bioenergetics’, which examines the effects of making significant changes to the foods we consume and which our body converts into fuel. The hypothesis here is that the brain’s metabolism – specifically the chemical processes that determine its take-up and use of energy – plays a determining role in neurological health and cognitive function.

One particularly exciting treatment-based study is currently being carried out by Professor Zoltán Sarnyai and his team at James Cook University, Townsville, with a group of patients who have been diagnosed with schizophrenia or bipolar disorder. Supported by a dietician, the patients have been put on to a strict ketogenic diet (as outlined below), and the results are proving life-changing. When I went to visit the team and meet with study participants, I heard moving stories about people with schizophrenia no longer hearing voices for the first time in thirteen years, those with bipolar disorder saying it was the first time their partner had ever known them to be free from the extreme veering between manic and depressive symptoms. People are finding relief from symptoms that led them to make repeated suicide attempts, and going back to college after years without employment, their family life transformed.

By seeking to understand some of the most drastic ways in which a human brain can become maladaptive, scientists are also discovering more about how healthy brains operate. The researchers suggest that a rigorous ketogenic diet, undertaken with medical supervision, could play an important part in the successful treatment of myriad other neurological and mental-health conditions, from diseases like Parkinson’s and Alzheimer’s to depression, addiction, anorexia, sleep disturbances and post-traumatic stress disorder. There are huge implications for all of us who want to preserve our

clarity of thought and protect against debilitating disorders and cognitive decline.

The starting point for the study in Townsville was the emerging consensus that schizophrenia and bipolar disorder can be understood as metabolic diseases. At first glance we might not see much overlap between metabolic conditions such as chronic obesity or diabetes, and severe psychiatric disorders. And yet doctors have observed that schizophrenic and bipolar patients have higher levels of both obesity and diabetes<sup>49</sup>, with severity and incidence increasing as their mental health declines. When they take blood samples from a schizophrenic patient who is having their first episode and is as yet unmedicated, they see altered markers for metabolism in the brain,<sup>50</sup> especially in the pathways that help create usable energy from glucose, and the way that neurotransmitters are created and degraded.<sup>51</sup> They also see altered metabolism and synthesis of the fatty acids that wrap around brain cells to insulate the transfer of electrical signals, as we saw above, a key mechanism in fast and accurate thinking. When doctors look at scans of their patients' brains,<sup>52</sup> they see decreased glucose metabolism in the frontal cortex, which becomes more pronounced as the condition progresses.

All metabolic processes, anywhere in the body, depend on the calories we consume every day: we eat to keep our blood pumping and our synapses firing. But the brain is particularly greedy. Although it constitutes just 2–3 per cent of our adult body weight, the energy it consumes represents nearly 20 per cent of the body's basal metabolic rate.<sup>53</sup> This means our energy-hungry brains are incredibly vulnerable to changes in metabolism. Researchers have been trying to understand exactly how the brain carries out metabolic processes, and crucially, how these can sometimes go awry, with disastrous consequences for downstream effects on connection and communication between neurons, and eventually on our mood and how we think.

If you're wondering whether the dreaded Western diet plays a part in driving symptoms of metabolic diseases including schizophrenia and bipolar disorder, you're absolutely right. Foods that are high in sugar and fat appear to be exacerbating the conditions' symptoms, which is why cutting them from people's diets has had such a profound effect. These foods are not themselves the cause of schizophrenia, bipolar disorder or any

other neurological or psychiatric condition. Rather, it's hypothesized that some individuals are born with the genes that predispose them to altered brain metabolism,<sup>54</sup> resulting in changes in brain bioenergetics from infancy, which then interact with environmental factors such as stress, trauma, viral infection, nutritional deficiencies and recreational drug use. The combination of these factors eventually creates profound changes in the brain, impacting not only how brain circuits are laid down in early childhood, but also how they are sculpted during adolescence. Eventually, these changes manifest as disorganized, chaotic and delusional forms of behaviour in adult life.

One method for tackling the brain's metabolic distress, developed for the treatment of epilepsy in the 1920s, is the ketogenic diet.<sup>55</sup> This approach, also known as metabolic therapy, involves massively reducing carbohydrate intake while increasing that of fat, on a ratio of one part carbohydrate to four parts fat. The normal metabolic process that breaks down carbs or complex sugars into glucose (the body's primary source of energy) is heavily curtailed and the body starts to utilize the ketones that arise from the breakdown of fat molecules instead. The metabolic switch goes like this: fat is directed to the liver, which metabolizes fatty acids to produce ketone bodies in a process called 'ketosis'. Due to limited dietary carbohydrates, the body is no longer able to break down carbohydrates into glucose, and ketones enter the bloodstream instead. Blood-sugar levels naturally come down, insulin sensitivity improves, helping with the symptoms of type 2 diabetes. Ketones are now in circulation and reach the organs, including the brain, that use them as a fuel source. This shift in fuel type changes the metabolic pathways throughout the body, causing a profound switch in how neurons operate, which triggers subsequent changes in behaviour. Returning to Mark Gallagher's world from Chapter 4 and using an F1 motor-racing analogy, it's like switching from diesel to a high-octane blend of petrol and ethanol. You end up with an entirely different metabolic system in operation.

The results can be life-changing. When I met Georgia, one of the participants in the Townsville trial, who has bipolar disorder, she told me that she'd struggled with her mood and energy levels all her life. 'I worked as a police officer for years until I got so traumatized I had to leave. I was diagnosed with depression around that time and nothing seemed to help. Then I was diagnosed with bipolar disorder and invited to join the

keto[genic] diet trial.’<sup>56</sup> The results have amazed and delighted her. Her mood and energy swings have stabilized almost completely. ‘On day nine into the diet I had a little manic episode that lasted three days, but I bumped myself back out of it and since then I’ve had nothing. My wife said the change was instantaneous. She stopped wondering what my personality was going to be when she got home from work because I was just happy, a calm presence. That has been really wonderful for both of us. I have the energy to do things now, and it’s consistent. Before keto I would need fourteen hours’ sleep at night and to nap between 11 a.m. and 1 p.m., just to cope with going into the afternoon and doing my job. Now I have consistent energy levels between 8 a.m. and 10 p.m. Recently I went for a run for the first time in three years, just stepped out of my front door and went. Now I go for a run every second day. I also have ADHD and I have been medicated previously. This diet gets rid of that. I’m so clear and calm and focused when I need to be. I can tell when I’m getting hungry or when I am low in ketones because I don’t have any focus and I’m foggy.’

Or there’s Paige, who was studying psychology at university when they had their first schizophrenic episode thirteen years ago. Paige also has diagnoses of autism, ADHD and borderline personality disorder and when their mental health was spiralling downwards, the voices in their head would explain in detail how they ought to kill themselves. ‘In the three years before the trial started<sup>57</sup>, I’d been in and out of the acute mental-health ward at Townsville hospital nineteen times,’ they told me. Being on the ketogenic diet has changed their life. ‘I haven’t had my own thinking for the last thirteen years because of the voices. It’s been like a crowded café in my head every day, and when they get closer it’s full-on chaos. But now I barely hear them. It’s like they’re sitting five tables back.’

Since they’ve been on the diet, Paige hasn’t had a mental-health crisis of the type that regularly used to take them into hospital. Like Georgia, they have lost weight and say that they now have plenty of energy, but of a more ordered kind. Unlike Georgia, Paige always struggled to sleep enough, typically surviving on three hours a night and dozing during the day, but now they sleep five or six hours at night and are establishing a routine for daily tasks. ‘I have so much energy and I’ve been able to do without some of my support workers, who were coming in seven days a week before. For me, being in high ketosis gives me too much drive, so I’ve learned to optimize it at a lower rate.’

Both Paige and Georgia talk about being less reactive and more emotionally regulated, more able to pause and consider. Paige says they are now able to realize that sometimes they're just having a normal reaction to a bad day, and use that realization to avoid going into meltdown. 'I have a lot more clarity about what I want and need,' Georgia told me. 'If I'm in a counselling session and something makes me uncomfortable, I notice. Before, I would get information overload or end up feeling really overwhelmed, caught up in flashbacks. It would take me a couple of days to process what had happened and think it through. Whereas now I'm able to go, "Hold on: actually, I don't like how I'm feeling about that. Can we go back and keep talking about it?" I'm able to reflect a bit more about the root causes instead of what I'm feeling in the moment.'

Paige has been able to tap into creativity and exercise their initiative during the trial, launching a non-profit company focused on supporting LGBT people with psychiatric illnesses. It's early days, but as they say, they would never have been able to do it without the clarity that the diet has given them. 'We have our first group counselling session later in the week. I've been doing paperwork, giving speeches. My idea is to have a space for the LGBT community, a safe space open seven days a week. We could run cooking classes, counselling sessions; that's my bigger picture, but we're starting with a support group, and we're doing events every month. I've already planned the clinical content and I'm out looking for donations. The diet is helping with my ADHD as well as the voices. I can self-regulate now. The stress of setting up the support group would have sent me to hospital before, whereas now I still need help but I can basically manage the feelings.'

How are these extraordinary improvements coming about? Ketones are a much more efficient fuel for the brain. Firstly, they reduce neuronal excitability<sup>58</sup> by increasing the activity of the natural GABAergic stop-signal nerve cells, which, as we saw previously, act as a brake on excitatory signals rushing across the brain. Schizophrenia is a condition of decreased GABAergic inhibitory transmission<sup>59</sup> – the stop and start signals are out of balance and as a result there is more neural excitability in the brain, helping to create those chaotic, disorganized thoughts.

But the physiological impacts of ketogenesis are vast: glucose metabolism typically creates reactive oxygen species (ROS) in the brain which, in large amounts and over a long time, can be harmful to neurons.



An unstable molecule that contains oxygen, ROS easily reacts with other molecules in a cell. A build-up of ROS in cells may cause damage to DNA, RNA and proteins, in addition to cell death, and has been linked to myriad conditions, from cancer to dementia. Ketones, by contrast, reduce this oxidative stress on the brain. Ketogenesis also seems to switch on anti-inflammatory genes, directing a cascade of responses<sup>60</sup> that help to mop up any circulating factors that might wreak havoc on brain physiology. Ketones also seem to be great at stabilizing brain networks, which is particularly good news as we age, as we will discover in the next chapter. All in all, ketogenesis seems to have a profound neuroprotective effect on the brain, helping it to run smoothly to promote clear, balanced thinking even in individuals who are grappling with psychiatric and neurological conditions.

Using this different fuel source also helps with weight loss<sup>61</sup> which, as we know, is beneficial for the brain as simply carrying significant extra weight is linked to cognitive decline. Weight loss has been one of the most positive changes for Georgia, who has now lost 17kg since she started on the ketogenic diet. Not only will this weight loss drive a cycle of clear thinking and better brain and metabolic health, it has also allowed her to be accepted on to an IVF programme that she was previously ineligible for on account of her weight. As Georgia says, the keto programme has been ‘life-changing’ for her in many ways. ‘I can start having babies!’ she told me with delight.

Zoltán and his team in Townsville are by no means the only ones carrying out this work. The research is growing apace and showing tremendous promise. A recently published pilot study also found that neurological changes induced by a ketogenic diet have profound impacts on clarity of thought in psychiatric patients. Over a four-month period, Dr Shebani Sethi, Clinical Associate Professor in the Department of Psychiatry and Behavioral Sciences at Stanford University, and colleagues studied twenty-one patients<sup>62</sup> (five diagnosed with schizophrenia and sixteen with bipolar disorder) who had been placed on a ketogenic diet, with analysis during ten visits spread over the trial. Those who successfully completed the diet experienced a significant reduction in weight (12 per cent on average), BMI (12 per cent), waist circumference (13 per cent) and visceral adipose tissue (36 per cent). Insulin and blood-sugar levels decreased dramatically. They



reported a 17 per cent average increase in life satisfaction and a 19 per cent improvement in sleep quality. Clinical severity decreased by an average of 31 per cent and, perhaps most strikingly of all, people with schizophrenia showed a huge 32 per cent reduction in symptoms. In the USA alone, dozens of similar clinical trials are currently testing the diet's effect on numerous conditions.<sup>63</sup> These include some much larger randomized and controlled studies. But even before the results are conclusively in, it's whispered that many patient groups and even doctors are advocating a supervised ketogenic diet alongside medication for a range of neurological and psychiatric conditions.

Many of us will struggle with anxiety, depression or addiction at some point in our lives and most of us, as we get older, will worry about developing Parkinson's or dementia, so the possibility of a diet-based intervention that is seriously effective at treating symptoms and delaying onset is exciting for virtually all of us. There are also many ketogenic diet proponents who claim it can improve emotional regulation and clarity of thought for all, even the young and healthy. It's an enticing prospect: more physical and mental energy, greater mental clarity, fewer mood swings, and all without medication.

There's a huge caveat here, though. A classical ketogenic diet is very low in carbohydrates, while being high in animal-fat-based products. It's so restrictive that it constitutes a medical intervention and can only be administered by a doctor and a dietician in tandem. That hasn't stopped keto diets being pushed as a panacea by enthusiasts and health influencers alike. I've seen memes on the internet of so-called 'caveman' diets, with plates full of red meat, fried eggs and not much else, which is absolutely not what I'm advocating here. If done poorly, a keto diet can be very bad for you, depriving your body of vital nutrients and risking damage to your gut microbiome. The unintended consequences for health, including brain health, can be severe. So it's not a lifestyle hack; more a heavyweight treatment for serious conditions.

That said, there are many less rigorous but still hugely effective versions of a keto-based way of eating that can deliver the majority of benefits without the drawbacks. From intermittent fasting to a modified Atkins diet, via an emphasis on low GI (glycaemic index) foods that release small amounts of glucose slowly, scientists are investigating the impacts of a whole range of variants on the same dietary theme.

All this research is shaping my own eating patterns. I'm consciously decreasing my carbohydrate intake while increasing my consumption of protein and healthy fats. I'm eating plenty of fibre-rich and relatively low-carb vegetables, like cabbage, celery, broccoli and beansprouts, to help those good gut bacteria to thrive. Rather than obsessing about being in ketosis, I'm focusing on reducing the less healthy choices and increasing the healthy ones as much as I can. For breakfast, for example, I'll have a coffee with cream; lunch might be a big plate of salad made with shredded raw cabbage, spinach, avocado and mackerel, sprinkled with mixed seeds and olive oil, and for dinner it'll be a steak or omelette with salad. It's the Mediterranean diet with a dash of keto and, for now, I feel full of energy and able to think clearly. Given my age, I'm probably heading towards the menopause soon, when low energy, mood swings and brain fog are all common, so it seems like a good time to start eating like this.

Our bioenergetic needs are greater at certain stages in life, with a correspondingly greater potential to create or maintain a healthy and flourishing brain, or risk succumbing to the inherent vulnerabilities to which our particular brain predisposes us. Early childhood and adolescence are prime examples of times when the brain is even more bioenergetically demanding, and vulnerable, than it is in adulthood. In a baby, the brain uses over 40 per cent of the body's daily energy quota,<sup>64</sup> and that percentage peaks at four or five years old, when the energy the brain utilizes comprises a whopping 66 per cent of the body's resting metabolic rate. In infancy and early childhood, our behaviour is characterized by being highly emotional, prone to mood swings and outbursts, but we are also learning intensively from our environment, soaking up new information like sponges. Brain energy demands then start to tail down until adolescence, which is similarly associated with emotional challenges, learning new skills and increased creativity. Our personal identity and understanding of other people as separate and valid beings with their own opinions and feelings are formed during this time. I find this very interesting. The facets of our behaviour that I believe are going to be increasingly important as this century proceeds – creativity and prosocial behaviours – undergo profound shifts at the very period in our life that our brain requires the most energy. This is an intriguing pattern and puzzle, and one we will return to in the next chapter.

## Balancing precision, creativity and empathy

Sometimes, our thinking needs to be precise to be effective. If you want to pinpoint what you think about an issue or come up with the correct solution to a mathematical problem, you need to be able to scan your stock of learning, filter information and hone your attention until you arrive at a particular end point. Precision is a huge part of what we mean by clear thinking and can be immensely valuable, but there is also a risk that being too attached to precision means we overlook the potential benefits of uncertainty, or the somewhat messier cognitive processes that drive creativity. Discarding information that doesn't fit with our existing view or resisting other ways of looking at things will quickly undermine our capacity to innovate and our emotional intelligence. Here is a classic example of the trade-offs that our busy brain must make on an ongoing basis to position us in that cognitive sweet spot and exploit the full range of our intelligence.

While there is a tension between the modes of thinking that drive precision and clarity on one hand and creativity and empathy on the other, and many of us believe intuitively that we're better at one mode than the other, there is also much evidence to suggest that the two are by no means in active opposition. In fact, most individuals are experts at switching between inward-focused thinking based on prior experience that scans our memory and interoception for what we already know, and novelty-directed associative thinking that looks outward for inspiration. We do it all the time without even noticing. Switching between these modes with ease is one of the hallmarks of cognitive flexibility, which Professor Barbara Sahakian, whom we met in [Chapter 2](#), has been studying, alongside her colleagues at Cambridge and at Nanyang Technological University in Singapore.

Cognitive flexibility is a core component of executive function, enabling individuals to adapt their thoughts and behaviours to changing demands. This type of mental agility is strongly linked to both clear thinking and creativity – but, interestingly, it is also largely independent of IQ. Barbara and her colleagues found that entrepreneurs who have created multiple companies<sup>65</sup> score more highly on this attribute than managers of a similar age and IQ. Cognitive flexibility is linked to many positive outcomes across our lifespan<sup>66</sup>, including better reading ability, social understanding<sup>67</sup> and

school performance<sup>68</sup> in children, and, in adults, better social decision-making, greater resilience,<sup>69</sup> quality of life<sup>70</sup> and protection against biases.<sup>71</sup> As Barbara explains: ‘That’s because people who are cognitively flexible<sup>72</sup> are better at recognising potential faults in their own thinking and using strategies to overcome them.’

As we saw when we were considering uncertainty tolerance or the importance of knowing when perseverance is no longer serving us, being mentally agile, flexible and open to new information is a key strand of intelligence in the twenty-first century. As Barbara put it: ‘This is not merely about changing your decisions<sup>73</sup>. Higher cognitive flexibility involves rapidly realising when a strategy is failing, and altering your approach. If there are roadworks on your usual route to work, what do you do? Some people remain rigid and stick to the original plan despite the delay. More flexible people adapt to the unexpected event and problem-solve to find a solution. Higher cognitive flexibility aids learning under conditions of uncertainty and makes it easier to negotiate complex situations.’

Barbara strongly believes that cognitive flexibility can be boosted. She’s exploring ways to do this, perhaps with computerized training via simple games, alongside more traditional and low-tech methods such as learning a new language or having more diverse social interactions. And gloriously, it seems that training your brain to boost your precision, logic and clarity of thought doesn’t have to come at the cost of dampening down your creativity or your empathy and altruism. The human brain is endlessly creative in finding effective workarounds in tricky situations, and even to overcome its own limitations.

Dr Reshane Reeder, whom we met in [Chapter 3](#), studies individuals like Geraldine with hyperphantasia, as well as its counterpart, aphantasia, in which people have very little or no capacity to conjure up images in their mind. As Reshane told me, it would be easy to suppose that

‘hyperphantasia correlates with extra creativity<sup>74</sup>, and aphantasia with groundedness and logical thinking, and that they’re completely different ways of thinking. But I think that’s much too dichotomous.’ Reshane is very interested in research on aphantasic artists, including those at Disney and Pixar, the American animation studios that have created films such as *The Little Mermaid*, *Beauty and the Beast*, *Tangled*, *Toy Story* and *The*

*Incredibles*. Glen Keane was a senior animator at Disney, himself an aphantasic.<sup>75</sup> His success inspired a survey of those in the profession, which discovered that a very high proportion of the other artists were also aphantasic. At first sight this was difficult to credit. As Reshanne put it: ‘If exceptional achievement in visual arts is correlated with a brain that produces rich mental imagery, how is that possible?’

But she has an explanation. ‘I think Glen Keane, who was very senior, trained his artists in an aphantasic way. He hit on strategies for working with and adapting to his brain’s repertoire of techniques and taught them to his team members; and once these techniques had proven themselves and word got out that the space was welcoming to people, the team attracted more aphantasic artists.’

One key strategy that Glen developed and taught to others concerned facial expressions for the characters he wanted to draw. ‘He would make faces while looking at himself in the mirror and draw what he saw,’ Reshanne explained to me. ‘He didn’t have a mental picture of the character feeling scared or falling in love, so he had to create it externally with his own face, and copy that.’ Glen found a creative workaround for his lack of mental imagery, which enabled him and a group of people who trained under him to create very detailed imagined scenes for a precise storyline even though they literally had no scope in their brains for picturing what they were drawing.

This is the sort of thing that fills me with awe and keeps me hopeful about humanity’s capacity to problem-solve and innovate. Autistic children can learn to exercise empathy, people like Paige and Georgia with severely chaotic thinking can eat their way to clarity, and artists like Glen with no visual imagination can play a key role in creating award-winning animated films. It’s precisely this enigmatic mix of clear thinking with creative problem-solving that is associated with our species’ greatest success stories and deepest personal well-being and satisfaction.

Let’s take stock. We’ve taken on board a wealth of information about how our brain operates, we’ve fed it with the nutrients it needs, our gut is sending it clear signals, we are thinking with clarity and precision while retaining our creativity and emotional intelligence. We are being flexible in our thinking, curious and playful in our explorative approach to the world. So, the next intuitive and logical question is, what precisely in the brain is responsible for helping to create the magical workarounds experienced by

Glen, Geraldine, Paige and Georgia? What exactly is giving their brains that super-boost despite, or in line with, their genetics? Here we are getting to the very core of how to build a brain fit for the twenty-first century. What is the incredible connector of it all? What underpins our cognitive flexibility, our emotional intelligence, empathy, creativity, imagination, thinking with clarity and precision, while at the same time permitting us to reflect and take the longer view? To answer this, we will need to zoom into our brains to examine them at the subcellular level while simultaneously zipping back 3.5 billion years. Buckle up and get ready for this revolutionary next chapter.

## **|EXERCISES|**

A brain fit for the 21st century is ... able to focus, concentrate and think with precision

- Help your mind to make meaning by reducing distractions, setting clear short- and longer-term goals, outlining your reasons for pursuing them and providing yourself with intermittent rewards as you complete tasks.
- Maximize the protein in your diet while decreasing the amount of processed and sugary food. This has been shown to help lessen disorganized thought. Stock up on fish, poultry, beans, nuts and seeds, which are all healthy, versatile sources of protein.
- Help your gut microbiome by making sure you have plenty of plant matter in your diet. The fibre from different plants encourages a diverse array of microbes to populate your gut and thrive there. They then send signals to your brain that not only improve mood but also cognition, including the ability to concentrate.
- Being able to focus and concentrate also requires periods of mental freedom. Give yourself time to mind-wander. I do this during daily exercise, not listening to podcasts or music, but allowing my mind to roam freely as I move. This explorative space will likely help you to zoom out, to see the bigger picture, and then be able to move forwards with both clarity and creativity.

## Creating Conditions for Wisdom, Expertise and Intuition

THE BIOLOGICAL REALITY OF AGEING CAN feel existentially challenging. We both fear and revere it, dread and (grudgingly) welcome it as proof that we've at least dodged the worse alternative. Given that we're living longer but not necessarily in good health, and that dementia and Alzheimer's overtook heart disease as the UK's leading cause of death in 2022,<sup>[1](#)</sup> perhaps this fear-tinged ambivalence is hardly surprising. In the past, when lifespans were shorter and people typically lived in smaller, more densely connected groups, the elders were venerated for their wisdom and insight. In our own disparate and more secular and commercial culture, the creativity and energy of youth are prized while ageing has become synonymous with decline and irrelevance. To this already daunting scenario we must now add the challenge posed by ageing alongside AI, which has an inexhaustible memory and virtually limitless powers to sort and analyse data. How can we possibly keep up?

I would suggest that we have an opportunity to return to cultivating the wisdom and sound intuition that our ancestors treasured and that we too can embody. Wisdom is built up from retained information acquired through experience and observation. It accrues through social connections as well as time spent in a job or through expertise in a particular field. Hard to measure but highly valuable, it takes many forms. It might be expressed by the experienced GP's hunch that their patient's symptoms merit being assessed by a consultant. It can manifest as the reassurance offered to a nervous new parent by an older relative whose children are now grown up. Wisdom implies a combination of learning and empathy, of intuitive



analysis of a situation and quiet confidence. To be wise is to know many things and have the grace to accept that you don't know everything.

With unlimited amounts of information at our fingertips, the skills that only experience can bring are set to become both increasingly necessary and valued, so long as we ourselves value and nurture them. It's by no means inevitable that we will get wiser as we get older. Curiosity, creativity and flexibility of thought all tend to decline as we age, but without them there is a risk that we will miss out on wisdom and get stuck with out-of-date ideas and less powerful thinking. If we can maintain our capacity to learn new things as well as remember the old ones, on the other hand, and deploy our expanding knowledge in ways that respond to the needs of the moment, then we're well on track for growing into wisdom.

So how do we go about it? How can we protect our intelligence in all its glorious range of cognitive skills, from memory to creativity and empathy to problem-solving? Are there strategies we can adopt that support our brain functioning throughout our lifetime, so that, rather like saving for a pension, we can bank the spoils of intelligence to draw upon in later life? New research in neuroscience suggests that there are, and that they relate to the inextricable link between physical health and cognitive functioning, specifically to the way that our body metabolizes fuel to turn it into energy.

In the last chapter, we looked at the fuel source part of this equation and saw that when our body switches away from glucose (its default fuel) to ketones, remarkable benefits accrue for people with highly disordered thinking. In this chapter, we'll be looking at the part played by the processes that drive energy production and use in our brain, irrespective of fuel source. We'll see how crucial it is for cognitive functioning and brain health to have a reliable energy source, especially as we age.

The reciprocal links between good health, a flourishing brain and measurable success across a range of different cognitive processes have been known for a long time. One of the most reproducible findings in psychology and neuroscience concerns the 'positive manifold'. This is the tendency for an individual who scores above average in one cognitive test, such as verbal reasoning, to score above average in others, such as spatial or numerical reasoning. If you think back to secondary school, you probably observed it yourself. If someone was good at, say, maths, they were usually also good at English and history. They may have preferred maths and felt they were stronger in it than in English, but broadly speaking that was a

matter of perception rather than significant measurable difference. Unless their genetics shaped their brain in a neurodivergent way and they had dyslexia, for example, then excelling in an exam for one school subject implied that they were probably able to pass others with relative ease. This is the positive manifold in action,<sup>2</sup> and it also spills over into more practical and creative tasks.

The phenomenon, which has been observed in study after study and across cultures, nations and races, has been explained by cognitive scientists as the product of a ‘general intelligence factor’ (usually shortened to G-factor), which suggests that some individuals have a higher general intelligence than others. First proposed in the first decade of the twentieth century by an English psychologist called Charles Spearman, the concept has been much developed and discussed, though never quite pinned down. The score on an IQ test is a reliable proxy for (albeit not a perfect representation of) an individual’s general intelligence.

What’s certain is that scores in general intelligence tests have been empirically proved to be predictive of a wide range of outcomes, in education, type of occupation and life. They have been systematically linked to physical health, successful ageing and even how long we might live, as Dr Iva Čukić and Professor Ian Deary of the University of Edinburgh showed in a definitive study whose results were published in 2017. They wanted to investigate whether there was a link between general intelligence and living a long life, so they set out to compare childhood IQ scores and survival to the age of seventy-nine, in one of the largest analyses of its kind ever undertaken. They traced 94 per cent of the individuals who, in 1947, had taken an IQ test at the age of eleven as part of Scotland’s Mental Survey: more than 70,000 people. Thanks to the huge size of the sample and the long time between testing and follow-up, they were able to show conclusively that the higher someone’s IQ at eleven, the longer they were likely to live.<sup>3</sup> (If you’re shaking your head and thinking, ‘What about diseases like cancer, or motor neurone disease, or random accidents?’, these outcomes also correlate with IQ, and we will come to an understanding of why that is the case later in the chapter.) The protective effect offered by a higher IQ affected mortality from all causes and applied to both men and women, but had a slightly stronger effect in women. Forty-five per cent of the individuals in the bottom 20 per cent of intelligence at age eleven survived to the age of seventy-nine, compared with 65 per cent

of individuals in the top 20 per cent. General intelligence, it seems, has an intimate relationship with physical health<sup>4</sup>.

Scientists have also demonstrated that the general intelligence of an individual remains constant across their lifespan. As we've seen in previous chapters, at a population level people typically display strengths in specific cognitive tasks at particular points in their lifespan. Children tend to be highly creative and good at lateral problem-solving, for example, whereas older people have accrued more information about the world, albeit generally at the cost of their creativity. But despite the waxing and waning in skills<sup>5</sup> and the slight decline associated with overall cognitive performance as we age, if you had a high IQ aged eleven compared to other eleven-year-olds, you will still have a high IQ aged seventy-nine compared to other 79-year-olds.

Cognitive scientists have been wondering for years about the underlying biological mechanisms that might help to explain the G-factor, in terms of both the consistency for individuals across cognitive skills and their lifetime, and the observable trends in populations. Is there some biological process occurring in the human brain that helps our neurons to flourish and generate the complex cognitive behaviours we've been examining throughout the book? How does this relate to ageing well, both physically and mentally?

This question is still the subject of much debate, but in the last few years there have been more clues pointing towards the generation of our body's energy supply as where the answer is most likely to be found. Our body needs to be able to turn fuel into energy, which it does through a process analogous to the burning of fuel that we use to supply our energy needs in the outer world. Just as burning things causes pollution in our external environment, so it does to us internally. Our body must maximize energy while minimizing the production of toxic by-products that might cause damage.

Central to all of this<sup>6</sup> (both for us and potentially also our planet's energy predicament) are miniscule, previously overlooked structures called mitochondria. There are on average 300–400 of these organelles in virtually every cell in your body, and they play a crucial role in the way your metabolism functions; in simple terms, they act as the body's network of power stations. Scientists have recently begun to suggest that it's these

mitochondria that supply the most fundamental biological mechanism underpinning the health of our cells and their capacity to fulfil their function. In the case of our neurons, that means our intelligence (including our creative, emotional and intuitive thinking, our ability to think longer-term, with clarity and precision). Could it be that mitochondria supply the answer to the long-pondered questions about an underlying general intelligence factor, and its links with physical health? Might tending to our mitochondrial health offer us a boost to our intelligence, well-being and resilience at any age, and help us to grow older with memory, creativity, cognitive flexibility and wisdom all intact?

Excitingly, the cutting-edge research into the role of mitochondria in creating an energy-efficient brain is crossing over with other studies on brain health, and their conclusions can be translated into relatively simple strategies that we can deploy in our own lives. Scientists are uncovering more evidence that lifestyle changes like increasing exercise, changing our diet and boosting social interaction promote the health of dendritic spines and mitochondria alike. (Dendritic spines are the structures that extend out of a neuron to find connections with neighbouring cells – see the image on [page 154](#).) These two aspects of our physiology – synaptic plasticity and mitochondrial function – are very much intertwined and, taken together, have huge ramifications for our thinking power and ability to fend off age-related cognitive decline and withstand dementia. But to grasp just how compelling the argument for making changes to boost our brain health truly is, we first need to understand a little more about the mitochondrial power stations that kick-started and shaped the long, slow formation of human intelligence.

## A brief history of mitochondria

About two billion years ago, a single-celled entity – our primordial ancestor – was living in an evolutionary rut. Then, theatrically, a fizzing burst of energy was created from a seemingly simple but momentous event. Two cells serendipitously joined together, one larger ancestral cell engulfing a smaller bacterial one. These two separate species merged,<sup>7</sup> to become one of the most enduring symbiotic relationships in biology. The larger cell provided a safe-haven bubble of oxygen and fuel, with which the bacterial cell was able to produce a perpetual power supply for its host. Their

relationship was the spark that ignited a process of evolution that led, countless iterations later, to all the cognitively capable multicellular creatures that exist on Earth today.

Hundreds to thousands of these ancient bacterial mitochondria sit in every single one of our cells (except the red blood cells, which are pretty much devoid of everything so they can maximize space for oxygen transport – crucial in oxygen-dependent energy production). This equates to approximately 10 million billion mitochondria, making up a whopping 10 per cent of your total body mass. Within each individual cell, the mitochondria undergo fission, to boost the cell's energy production and serve their host's energy demands. Neurons are particularly mitochondrially rich; each one contains thousands of mitochondria, accounting for around 40 per cent of the neuron's cellular volume. Weight for weight, you are more mitochondria than you are brain, which makes up on average only 2 per cent of your body mass. These statistics, to me, are mind-blowing. Each one of us is reliant on a network of bacteria that entered our ancestral cells and kick-started our evolution two billion years ago. And yet, when I was a doctoral student twenty or so years ago, these power stations that fuel our thoughts were rarely mentioned.

We now know that mitochondria have their own genome, a set of around thirty-seven genes that originate from that ancient bacterium. Some of the mitochondrial genes instruct the creation of energy, transforming the food we eat via oxidative breakdown into a new type of fuel molecule that the cell is able to make use of: adenosine triphosphate (ATP). This is our metabolic currency, used in the energetic exchanges that power all bodily functions, including muscle contraction (so that we can move, for instance, or communicate with one another through speech), creating nerve cell impulses (so that we can process information from the outside world, to think, feel and instruct the relevant part of the body to react), underpinning synaptic plasticity (so that we can learn and remember from our environment) and enabling neuronal growth and branching as our brain circuits develop and change, and as new brain cells are born throughout our lifetime.

Our mitochondria work hard. Across the body, they produce nearly 50kg of ATP every day. According to the English biochemist and writer Nick Lane, 'Gram per gram, even when sitting comfortably<sup>8</sup>, you are converting 10,000 times more energy than the sun, every second.' The brain, as we

know, guzzles fuel and produces and consumes vast amounts of energy in the form of ATP. It's estimated, for example, that just the outer layer of neural tissue, which plays a vital role in memory, attention, perception, awareness and consciousness, consumes about 5.7kg of ATP per day.<sup>9</sup> (This is more than the weight of the human brain, though there is considerable recycling of these molecules.) A lot of energy is required simply to maintain the ion gradient at the neurons' membrane so that the action potential – that zip of electrical current – can transfer information from one neuron to another. In fact, each individual neuron in your brain creates and uses about 4.7 billion ATP molecules per second just to keep ticking over.<sup>10</sup> These energy requirements increase by approximately three and a half times<sup>11</sup> to sustain a thought. From the nerve cell movement and shape changes required to support synaptic plasticity to the maintenance of the nerve cell's fatty layer that insulates the electrical signal so it can flash across the connectome, we owe our mental agility to the vast mitochondrial energy creation that acts as a foundation for these fundamental cellular processes in our brain.

Other mitochondrial genes are involved in helping to identify and clear away any mitochondria that are damaged. There are also genes for helping to store calcium, which is an essential chemical for both muscle contraction and nerve-impulse generation, and mitochondrial regulation. Mitochondria also contribute to the biosynthesis of several neuroendocrine factors such as cortisol, which helps to execute the stress response, and oestrogen, which helps promote synaptic plasticity.

When mitochondria stop functioning, their host cell is starved of energy, and depending on the type of cell, symptoms of poor mitochondrial health vary widely. Generally, cells that need the largest amounts of energy, such as those of the brain (including neurons), heart, liver and gut, are most affected by faulty mitochondria. When the mitochondria in our brain's cells are struggling, the impact on how we think and feel, perceive and respond to the world can be profound.

Even when our mitochondria are healthy, the constant energy generation they support results in toxic by-products, the build-up of which is increasingly being linked to symptoms of ageing throughout the body. Given the high density of mitochondria in our neurons (itself unsurprising as the brain is so energy-demanding), toxic build-up there is particularly



likely, and can have significant consequences. If mitochondrial health goes awry earlier in our lives and toxic waste products begin to accumulate, they can contribute to hallucinations, paralysing anxiety, deep-seated depression and chronic fatigue. As we age, they might be predictive of whether and when we will develop chronic neurodegenerative disease, as well as being linked to our longevity. No wonder scientists are leaping on mitochondria to explain some of the most difficult questions around brain health as well as intelligence: these still poorly understood organelles seem to be far more important than previously thought.

## How energy supports intelligence

In 2024, Professor Oliver Howes and his colleagues<sup>[12](#)</sup> at the Psychiatric Imaging Group at Imperial College London wanted to test the idea that mitochondria were key to both intelligence and health. Longitudinal data from meta-analysis such as Iva Čukić's study was compelling, but to a cellular biologist such as Oliver (or myself) it posed urgent questions over which were the key molecular factors involved. Oliver and his group were also motivated to follow up a previous seminal study<sup>[13](#)</sup> by Dr Bianca Brawek and colleagues at the University of Freiburg in Germany, which showed that raised mitochondrial metabolic activity, creating more ATP, was linked to higher cognitive performance.

Oliver knew that one enzyme, mitochondrial complex I (MC-I), was the largest and most crucial in a process called oxidative phosphorylation (OxPhos): the chain of respiratory events that takes place in a cell to produce energy. He also knew that, thanks to some clever work by his colleagues, it was now possible to trace and measure MC-I distribution<sup>[14](#)</sup> in a living human brain using a new scanning technique known as PET (positron emission tomography). Taken together, these two things meant that there was a way of mapping mitochondrial activity in the brain in real time.

Oliver and his team ran a small pilot study with twenty healthy volunteers, with a mean age of thirty-seven. The volunteers were put through a series of cognitive tests to measure their IQ performance, then their brains were scanned to see how much MC-I they contained, and where. This served as a proxy for brain energy production. What the team

found was that the higher a person's IQ score, the higher the amount of MC-1 in the brain. This led them to propose that higher cognitive performance is achieved by increasing the overall energy availability within certain brain networks involved in cognitive tasks. In essence, the more energy your brain can produce, the greater the chance that you can think intelligently. Which makes perfect sense.

In support of this, Dr Yuko Hara and colleagues at the School of Medicine<sup>15</sup> at Mount Sinai, New York, carried out a study on monkeys' brains that found a clear link between the number and shape of mitochondria in the animals' synapses and their intelligence. The team analysed the presynaptic terminals in the prefrontal cortex of rhesus monkeys and discovered that mitochondrial density and functional shape were predictive of the ability to retain information in working memory. Monkeys with strong working-memory skills were found to have higher numbers of functional mitochondria, whereas individuals with poor skills had larger numbers of malformed mitochondria, suggesting oxidative stress build-up and lower ATP production.

These exciting developments shed light on the processes underpinning the link between brain function, intelligence and longevity. The emerging evidence underlines the conclusion that a healthy brain capable of sophisticated cognition is one that has a reliable energy system in place, and that this mitochondrial system becomes fragile when our general health is poor, and as we age.

The links between mitochondria and intelligence are proving so compelling for scientists that there has been a boom in all sorts of lines of investigation, including whether our exclusively maternal inheritance of mitochondria – the fact that we inherit all our mitochondria from our mother and none from our father – might help to account for some of the variation between men and women in distribution of intelligence scores<sup>16</sup> and age at death, which scientists observed in the Scottish cohort. There is a wider distribution of intelligence at both the lower and higher end of the distribution curve for men than there is for women, who tend to cluster slightly closer towards the centre. There are doubtless many factors that affect this distribution, but one of them might be maternal inheritance of mitochondria. This might also be part of the reason that a child's general intelligence seems to follow their mother's,<sup>17</sup> rather than their father's, IQ

score. It's not that nuclear DNA from the sperm as well as the egg have no role to play in characteristics that shape mitochondrial health, more that males have been forced to evolve extra features to cope with the lack of mitochondrial DNA. Any variation in mitochondrial DNA<sup>18</sup> that is favourable or neutral for females will be retained, even if it's not favourable for males, who have no evolutionary mechanism for purging it. Without this mitochondrial origin buffer, there is a higher chance of accruing either an advantage or a disadvantage, which might explain the intellectual spread we see in males.

As Professor David Geary, a cognitive scientist and evolutionary psychologist at the University of Missouri, explained to me: 'The mitochondrial DNA inherited from mothers provides some of the core genes<sup>19</sup> needed to construct the energy-generating mechanisms required by the brain, but these are also dependent on nuclear DNA inherited from both parents. Certain combinations of mitochondrial and nuclear genes seem to be especially good at promoting energy generation, which in turn is associated with slower ageing and better cognitive abilities. Males without many of these favourable nuclear-mitochondrial combinations may age more quickly and show compromised cognitive abilities related to males with more of these favourable combinations.'

## Bioenergetics, brain health and ageing

Whatever their sex, individuals age at very different rates from one another depending on their unique physiology. If you look around at the people you went to school with or at the members of any other long-standing friendship group, you will see huge variation in terms of physical and mental health and outward appearance among people of similar biological age. Some seem almost to defy the ageing process, remaining a fountain of youthful vitality and energy well into later life. Others are weighed down by the passing years as life takes its toll on their outlook and burdens their bodies. This individual rate of ageing can be better understood by reducing it to its biological processes and cellular components. It's an incredibly complex dynamic, which is shaped by many different contributing factors.

A decline in mitochondrial quality and activity<sup>20</sup> has been associated with normal ageing, and is also correlated with the development of a wide

range of age-related diseases. Mitochondria are part of the reason why kids seem, on the whole, full of energy: they have a ton of young, vibrant mitochondria with healthier energy-production capabilities. Mitochondria replicate themselves through a process called ‘mitogenesis’, dividing to form new cells to maintain a healthy population. Defective and dead mitochondria are shuttled out of host cells and cleared away in a process called ‘mitophagy’. Over the course of a lifetime these processes slow down and become inhibited, so that dysfunctional mitochondria eventually outnumber the healthy population in the host cell. The accumulation of damaged mitochondria<sup>21</sup> has been definitively linked to the exacerbation of neurodegenerative and cardiovascular diseases, cancer and inflammation in general.

There’s also a new hypothesis circulating in scientific fields that ageing is fundamentally a condition of mismatched energetics,<sup>22</sup> with energy production slowing down as the body simultaneously makes increasing demands on it. Damage to the cells accumulates with age, which increases the amount of energy expended on repairing, replacing or clearing away defective or dead cellular material. At the same time, the amount of energy available to us is gradually declining as our pool of mitochondria shrinks, along with their efficiency. The brain must act as mediator and broker in this energy economy and take drastic yet entirely logical measures in response to the shrinking energy budget. It starts to conserve energy by suppressing low-priority processes, and this can produce fatigue, physical inactivity, blunted senses and a decrease in our immunity or increased inflammation. Anything we can do to boost mitophagy and mitogenesis, and so help to close that gap between energy demand and supply, can only be a good thing for stable thinking, general well-being and longevity.

Returning to that early seminal mitochondrial study that inspired Oliver Howes, it also demonstrated that, if the by-products of energy production accumulate, they can cause damage to cells. Build-up in the brain triggers cognitive decline and contributes to Alzheimer’s and dementia.<sup>23</sup> But here’s a paradox: the oxidative respiratory phosphorylation process<sup>24</sup> by which mitochondria produce both the crucial ATP from the fuel we eat, and its waste products, is also the main way our body generates reactive oxygen species (ROS). At moderate levels, these ROS molecules have an important role as signal mediators in various processes taking place in the cell. They

are linked to higher performance in tests of executive functions, with greater brain metabolic activity and performance being associated with slightly increased ROS levels. But (and this is a big but) while ROS are both necessary and extremely beneficial up to a certain point, they can be dangerous to the cell if ROS production becomes uncontrolled. The very integrity of mitochondrial DNA can be endangered precisely by the action of ROS. Several studies have suggested that elevated ROS formation and accumulation<sup>25</sup> is linked to the ageing process and a less flourishing, less resilient brain, even at a younger age.

Another important contributing factor to cognitive decline as we age is the gradual erosion of telomeres on the DNA in our brain cells. A telomere is like a protective cap<sup>26</sup> at the end of each chromosome, akin to the plastic casing at the end of a shoelace that helps to protect the shoelace (or indeed the DNA in this analogy) from fraying with use and eventually unravelling. Telomere shortening is an inevitable part of being alive: with each round of cell division, the telomeres get worn away until eventually there is nothing left to protect the DNA. At this point the nucleotide sequence of the DNA itself will start to erode, making it harder to code the formation of proteins vital for that cell to function. Mutations and errors begin to accumulate. Eventually, new cells are no longer able to form to replace the ageing ones, and the cellular turnover that is crucial to maintain a healthy organism slows to a stop. The cell dies. When enough cells die and the failure becomes systemic, that's the end of us.

This so-called 'end replication problem' was identified almost half a century ago, and much research has been conducted since then. We now know that when telomeres have been critically shortened, they initiate a cascade of events that promote cell death<sup>27</sup> to help protect the wider host, as otherwise the DNA will become eroded, causing genetic mutations that could lead to widespread issues. We also know that altered telomere length is linked to higher risks<sup>28</sup> of developing a raft of conditions, from neurodegenerative diseases to cancer and cardiovascular arrest. Telomere length is considered a marker not only of chronological but of biological ageing, overall individual health and prospects of mortality.

Fortunately, there is a wonderful antidote to telomere shortening: telomerase, which is an enzyme that helps to protect and repair telomeres. Unfortunately, telomerase also becomes less active as we age.<sup>29</sup> In

addition, certain lifestyle factors such as smoking diminish it.<sup>30</sup> Recently, a study by Professor Elissa Epel<sup>31</sup> and colleagues from the Department of Psychiatry at the University of California, San Francisco established that chronic stress and poor mental health are also associated with decreased telomere length and altered telomerase activity. When the team analysed blood samples from healthy pre-menopausal women, they found that in those with the highest levels of perceived stress, telomeres were shorter on average by the equivalent of at least one decade of additional ageing, compared to women with lower stress levels. It's long been known that stress is bad for our health, so intuitively this makes sense, but this is one of the first studies to link stress to a specific biomarker that allows us to say why and how it has such a negative effect on how we age. Elissa's conclusion was that 'at the cellular level, stress may promote<sup>32</sup> earlier onset of age-related diseases'. (Interestingly, exercise, particularly of the high-intensity<sup>33</sup> aerobic variety, seems to help boost protective telomerase activity and telomere length, which partly explains why it's linked to healthy ageing.)

There's increasing evidence that ageing, telomeres and mitochondrial function are all intimately linked. It is now thought that impaired mitochondrial activity and impaired cellular bioenergetics can cause faster telomere degradation, possibly through a reduced capacity in telomerase production. A consortium study of 690 patients with mitochondrial disease by researchers across the USA and Europe<sup>34</sup>, and led by Associate Professor Martin Picard at Columbia University, found that they were experiencing 'hypermetabolism'. Their resting energy expenditure was elevated; in other words, it cost them considerable energy simply to exist at a baseline level, let alone perform extra activities. These patients were in effect living in an energetic cost-of-living crisis analogous to the current financial one that has been making life difficult for so many. The investigating team found that this high energetic cost accelerated telomere erosion every time cells divided.

Elissa and Martin were interested in this newly discovered link between mitochondria and telomeres, specifically in relation to life stress. In 2024, they investigated further by analysing blood<sup>35</sup> samples taken from mothers of autistic children and comparing them with mothers of neurotypical children (92 stressed mothers and 91 control mothers, respectively). Over a



nine-month period, their team took samples to test for telomere length and telomerase activity. They also looked at mitochondrial enzyme activity and assessed overall mitochondrial health by counting the number of copies of mitochondrial DNA in each blood cell: the higher the number, the more mitochondria each cell has. The team integrated that information with other metrics of energy transformation capacity to produce a measure of mitochondrial health – the mitochondrial health index (MHI). They then compared all this data with the volunteers' self-reported stress levels.

They found that individuals with higher baseline mitochondrial health (indicating greater energy transformation capacity) maintained higher telomerase activity during the nine-month period, compared to those women with lower baseline levels, who on average experienced drops in their telomerase activity. They also found that the high-chronic-stress group of mothers showed both reduced mitochondrial health and a faster decrease in their telomerase activity. Based on other experiments involving exposing cells in a Petri dish to a glucocorticoid stress hormone, they knew that stress can cost about 60 per cent more energy, and that stressed cells that become hypermetabolic age faster, and die earlier. This allowed Elissa and Martin to conclude that chronic stress seems to make it harder for the mitochondria to provide a reliable source of energy to cells, which in turn has an impact on maintaining telomerase activity. The combined effect would speed up the death of cells, with all the associated risks of higher disease and swifter ageing.

The bottom line seems to be that to maximize your brain function at any age and grow older with your cognitive faculties primed to flourish, you need your body to be able to produce energy efficiently and maintain cellular health. Your mitochondrial health is crucial for this. But this relatively straightforward concept gets complex as we add in factors such as stress, perception of life events and sociability, as we shall see.

## Healthy mitochondria support lifelong well-being and resilience

The list of aspects of our brain functioning related to mitochondrial health continues. It's not only tied to our energy levels, our intelligence and healthy ageing, but connected to our personality and our resilience to stress.

An early hint at this possibility came via a study of unlikely organisms: fruit flies and honey bees. In 2014, it was discovered that inhibiting mitochondrial respiration<sup>37</sup> so that nerve cells were unable to create ATP correctly, affects how these organisms interact socially. Specifically, it increases instances of aggression between individuals. Researchers wanted to explore if, and how, this link between social interaction style and mitochondrial function might play out in humans.

One line of investigation was to try to establish a link between personality and mitochondria. It was already known that the set of well-classified personality traits known as the ‘Big Five’ (extraversion, agreeableness, openness, conscientiousness and neuroticism) were associated with both energy levels and an individual’s longevity, indicating a putative link with mitochondria.

In 2022, a team of scientists at the US National Institute on Aging<sup>38</sup> looked at data obtained from 722 participants from the Baltimore Longitudinal Study of Aging, the nation’s longest-running study of human ageing. They analysed blood samples for their mitochondrial DNA count to assess mitochondrial health, and related this to the results from the standard ‘Big Five’ personality test. The team found that people with a higher mitochondrial DNA copy number (the number of copies of mitochondrial DNA) in their blood cells, which functions as a biomarker of good mitochondrial health, had higher levels of extraversion, openness, agreeableness and conscientiousness, and lower levels of neuroticism. Tracking people’s outcomes over the next few years showed that they also had a lower risk of depression and early death. This was the first study to establish a strong connection between personality traits, mortality and a mitochondrial parameter. The scientists hypothesized that personality traits were influencing mitochondrial function, which was in turn influencing mental health and mortality. But was it just a spurious finding? The team set out to replicate it in a separate group of people and repeated the study, this time looking at data from 587 Italian participants in the SardiNIA Project. They got the same results.

Then, in 2024, a team of researchers based at Columbia University<sup>39</sup> explored this idea further. They wondered if mitochondrial health might also underpin how positively you experience your life – your general well-being. Assistant Professor Caroline Trimpff is the lead author of a recently



published paper on their long-term study involving nearly 450 older American adults. These participants had answered a series of detailed questions about their lifestyle at various points over the preceding two decades and donated their brains at death for postmortem analysis. Researchers examining the donated brains focused on the dorsolateral prefrontal cortex, a brain region involved in executive functions and emotional regulation, and analysed it for mitochondrial proteins. They discovered that the brains of those individuals who had cited a greater number of more positive experiences – including being part of a larger social network, taking part in more social activity, having a strong sense of purpose and overall positive well-being – showed huge increases in certain proteins indicating mitochondrial activity. In particular, they had raised levels of those involved in oxidative phosphorylation (OxPhos), the key process in the cells' production of ATP, and the same pathway that Oliver had been investigating at Imperial College London. It was beginning to seem that, just as efficient energy production and better cognitive performance go together (as Oliver had observed), so too do energy production and life satisfaction. In contrast, people who had reported a higher incidence of negative life factors, such as social isolation, depressive symptoms, low mood and perceived stress, had much lower amounts of these mitochondrial proteins in their brain.

As Caroline said of the study's findings: 'We're showing that older individuals' state of mind<sup>40</sup> is linked to the biology of their brain mitochondria, which is the first time that subjective psychosocial experiences have been related to brain mitochondrial biology.' The research team estimated that these psychosocial experiences accounted for 18 to 25 per cent of the variance in the abundance of the MC-I (mitochondrial complex I), which is the largest enzyme in the OxPhos pathway of energy generation, involved at the very beginning of the process.

Caroline and the team at Columbia believe that the higher the level of MC-I, the greater an individual's ability to transform energy, which is linked not only to higher cognitive scores but also more positive psychosocial factors and a more positive state of mind. This finding is unsurprising to a certain extent given that, as we've learned, positive emotions and a healthy lifestyle are inextricably linked to building a well-functioning, intelligent brain that flourishes into the longer term. Nevertheless, it's fascinating to see brain biology and personal well-being

knitting together in this measurable way. It should prompt us to take seriously our need for social connection and a sense of purpose, especially since activities related to them are among the most likely to foster wisdom as well as life satisfaction.

Research is expanding at pace into aspects of our mental health and emotional lives once considered too nebulous for neuroscience to tackle. In 2025, a study into the links between social isolation<sup>41</sup> and markers for brain health was conducted by Professor Barbara Sahakian of the University of Cambridge (whom we met in chapters 2 and 5) and colleagues at Fudan University. The team analysed blood from a whopping 42,062 participants who had donated samples to the UK Biobank, screening it for over 2,920 proteins. They asked the study participants about their feelings of loneliness (which is a matter of personal perception – you can feel lonely even if you appear to be surrounded by loving friends and family) as well as their actual level of social contact.

What the researchers found was striking: the protein most closely associated with social isolation, and also linked (albeit to a lesser degree) with perceptions of loneliness, was growth differentiation factor 15 (GDF15) – a marker of cellular and mitochondrial energetic stress<sup>42</sup> that is linked to physical and mental illness, ageing and premature mortality. When I spoke to Martin Picard (who has worked with both Caroline and Elissa) about his extensive work in mitochondrial health, he could barely contain his excitement as he explained this result to me. ‘The number one protein that comes out<sup>43</sup> is the best marker of mitochondrial energy stress that we know. This is remarkable!’ It seems that if we lack social connections, we’re not only missing out on a boost to our mood and opportunities for learning but literally sapping our energy to live. This is particularly crucial for older adults who are already battling the inevitable effects of brain ageing caused by slowing energy production and telomere erosion.

Martin believes that GDF15 is the key signalling molecule in the brain’s monitoring and regulation of the supply and demand of energy at a cellular level. Much as the brain has to bring together all the information gathered by our sense organs and process the data to stimulate action, it must also, he argues, monitor the body’s energy use, determine how much is available and prepare for any difference. This process is called ‘metoboception<sup>44</sup>’. When the brain detects an energy gap (in times of stress, for example),

GDF15 activates a cascade of reactions called ‘mitoception’ to induce energy conservation, which ultimately results in a psychological response such as fatigue or anxiety.

Stress in biological terms means any activity that pushes systems out of the state of balance needed to function correctly and this includes when energy demand exceeds availability. If Martin is right, this would explain why GDF15 is elevated by stressors such as strenuous exercise and has a lower baseline level in those people who exercise regularly, as well as going up as we age and when we’re ill. Higher levels of GDF15 are even registered during the energy-hungry process of pregnancy, where they are associated with morning sickness, which can be understood as the cost of the body focusing its energy on the higher-priority task of supporting the embryo’s development.

Stress is of course inevitable in life, whether we’re talking about the everyday stressor of sprinting to catch a bus or the complex systemic stressor of a life event such as bereavement, which will induce a whole-body/brain response. If we can boost the health of our mitochondria, perhaps we can influence the energy flow in our brains to increase our resilience to stress? The emerging research on the intertwined effects of cellular energy supply, personality, mood, social contact and well-being point the way to nurture the positive aspects of human life that help us all to thrive. If we’re to turn our life’s experiences into a stock of wisdom (albeit sometimes hard won), then we need to be able to navigate rather than succumb to stress.

## The epigenetics of mitochondria: how bioenergetics can shape a legacy

We saw in [Chapter 3](#) how environmental stressors – life experiences, stressful associations and newly acquired knowledge – might be passed on to our children, and even their children. This experiential inheritance is not transmitted via the standard route, in the nuclear DNA sequence, but in the conformation or shape of our DNA. Changes in the DNA’s shape allow enzymes to access the genes in different ways, which in turn affects the transcription of proteins, the building blocks for life, and hence the cell’s operation and fate.

These epigenetic changes are a bit like inherited memories wrapped around our DNA. Sometimes they can be highly adaptive, allowing for a shortcut to incorporating useful information so the next generation can adapt immediately and pass this adaptation across multiple generations. Epigenetic changes help to ensure that our descendants can unconsciously hold our experiences in mind, their neural circuitry having been shaped by their predecessors' experiences, regardless of the DNA code itself.

Epigenetics, especially in relation to behaviour, is still a very new area of research – the first pivotal papers were published around 2014<sup>45</sup> and have subsequently been widely cited. Since then, a new sub-field has emerged, relating not to the DNA in our cells' nuclei but, you've guessed it, to our mitochondrial DNA. Mitoepigenetics is in its infancy but is making exciting strides in understanding how the impacts of our ancestors' life experiences, surroundings, diet and exposure to toxins are reflected in our mitochondrial DNA. The mitoepigenetic changes we inherit can swiftly alter our bioenergetics, affecting the capacity of our mitochondrial cells to produce energy, and can be passed on to our descendants, as is the case with nuclear DNA. Some of these changes are likely to be highly adaptive, but they have also been associated with mitochondrial dysfunction during ageing and implicated in a wide range of brain conditions, including unhealthy ageing<sup>46</sup> and neurodegeneration (namely Alzheimer's, Parkinson's and amyotrophic lateral sclerosis), and conditions relating to clarity of thought<sup>47</sup> and our ability to socialize (namely bipolar mood disorders and depression).

The value in understanding the implications of epigenetic changes lies in the fact that they take hold in the lived time of our individual lifespan. This means they will potentially yield guidance for behavioural changes we can implement now that will not only support healthy brain functioning for us but also shape the legacy we're able to pass on to our descendants.

## Boosting your mitochondrial health for maximum bioenergy

I met Nate for the first time in 2020, in Queensland, Australia. Over the previous fifteen or so years he had been on a journey to dramatically change his lifestyle with the sole goal of optimizing his mitochondrial health. Nate

had experienced significant health problems all his life, having been diagnosed with retinoblastoma, a form of eye cancer that particularly affects children, at eight months old. Nate was born with an RV1 mutation to his RB1 gene, which plays a role in suppressing tumours. He had radiation treatment for tumours on his eyes when he was a baby, which saved about 10 per cent of his retinal tissue and means he still has a small amount of vision. Then, when he was twenty-four, he was diagnosed with testicular cancer, which had already metastasized. ‘They caught it just before it got to the liver,’<sup>48</sup> he told me. ‘I had surgery to remove the left testicle, then chemo for three and a half months before getting the all-clear. Throughout that time I was researching anything and everything that might help my recovery. I learned a lot about mitochondria.’

Nate is now in his mid-thirties and looks the picture of health. Intelligent, articulate and passionate about well-being, he believes he was predisposed to be susceptible to cancers because of inherited mitochondrial dysfunction. Alongside the full repertoire of conventional medicine on offer, including surgery, radiotherapy and chemotherapy, he is also applying findings from the emerging research on mitochondria to his lifestyle in the hope that it will optimize his health and help him to feel in control of his condition. He now lives in Mexico and calls himself a ‘mitochondriac’. Nate rises each day in time to watch the sunrise in the belief that exposure to early-morning sunlight will help to regulate his circadian clock and energize him. He swims every day in the ocean, fasts regularly, is careful with his diet and goes to bed as the sun sets. ‘Despite twenty-six eye and brain diagnoses, genetic mutations and damage from chemo, I’m healthier, happier, more mentally alert and more energized than most other people I know,’ he says. ‘That doesn’t make sense to me. I think it shows that we’re living with an epidemic of brain disease because we’re not looking after ourselves properly.’

Given everything we’ve been uncovering about the links between our mitochondria’s effectiveness and myriad behaviours – from intelligence in general, social style, personality and resilience, to healthy ageing, longevity and how we pass on a successful bioenergetic legacy – perhaps Nate’s approach to his underlying health issues makes sense. For all of us, whether or not we have significant ongoing health problems, the question of what we can do to support our mitochondria feels compelling. How can we intervene to maximize their chances of creating the energy we need to think

with full brain power while minimizing the accumulation of hazardous by-products?

The deceptively simple answer seems to be: adopt a proactive approach to taking care of our physical health. We don't need to redefine ourselves as mitochondriacs, move to Mexico or take up a ketogenic diet to do this. Focusing on mitochondria can offer a helpful framework, though, given that they affect our whole body but have an outsized impact on brain health, and the interventions that support them are relatively straightforward to adopt. Professor Zoltán Sarnyai, who is implementing ketogenic diets for his psychiatric patients, as we saw earlier, gave me a concise but comprehensive overview of his position on how we can all stay as happy, healthy and smart as possible throughout our lifetime. 'I think metabolic health is key for healthy brain ageing,'<sup>49</sup> he told me. 'If we look at the recent large reviews in *Lancet Neurology* about age-related cognitive decline, it's estimated that about 40 per cent of the contributing factors are avoidable. People who exercise, eat healthily, make sure they're not getting overweight or obese in mid-life, keep intellectually active and stay socially connected all have a decreased likelihood of developing age-related cognitive decline. That point about social isolation is still under-appreciated but we know that being isolated has a very detrimental effect on cognitive functioning. Possibly via age-related hearing loss, which contributes to social isolation, which then contributes to depression and a chain of withdrawal that pushes people quickly towards cognitive decline. I would suggest screening your hearing from the age of sixty.'

Sound and sensible advice, which is echoed by Associate Professor Picard. Martin and his team have developed a concept called energy resistance (eR),<sup>50</sup> which accounts for the behaviour and transformation of energy in the wet, carbon-based circuitry of biology. This concept of eR helps to explain the theory that both normal ageing and many of its associated diseases stem from the shortfall in the body's energy budget, which as we've seen tends to increase as we get older, partly due to mitochondrial dysfunction. Energy resistance is the fundamental property that enables food to be converted into energy for use throughout the body so that we can live. Excessive eR leads to bioenergetic inefficiency, reductive and oxidative stress, inflammation, molecular damage and memory loss, while eR is minimized, on the other hand, by sleep, exercise and restorative interventions that promote healing.



Martin, like Zoltán, is an advocate for making simple changes to our lifestyle to offset our energy resistance, maximize the positive impact of the energy flowing into our system and help us to lead a flourishing and long life. ‘I think it all boils down to how energy flows through your mitochondria,’ he said as he explained energy resistance to me. ‘If it doesn’t flow well, reactive oxygen species are produced in bigger quantities. Anything that increases the flow of energy through your mitochondria will tend to lower energy resistance and could reduce the impacts of ageing on your brain. They’re simple things: moving your body more, not eating too much, maintaining nourishing social connections and cultivating positive psychological states.’

## *Moving for our mitochondrial health*

One familiar yet profoundly impactful strategy is to take regular aerobic exercise. The general rule of thumb is that any exercise that gets your heart pumping and sweat glands dripping will not only improve your health in important ways – reducing your risk of heart disease, stroke and diabetes, helping you to lose weight and improving your mental health, protecting against memory loss and diseases of ageing such as Alzheimer’s by enlarging your hippocampus – but also support the mitochondria in your body to do their job.

We have seen throughout the book that aerobic exercise is consistently linked to measurable improvement in brain health and function. Dr Kirk Erickson of the University of Pittsburgh<sup>51</sup> and his colleagues conducted a trial with 120 older healthy adults, and showed that aerobic training (in this case simply going for a fast forty-minute walk three times a week) increases the size of the hippocampus by on average 2 per cent, leading to improvements in spatial memory. Professor Alison Yung and colleagues at Manchester University<sup>52</sup> report that patients with bipolar disorder and schizophrenia experienced a significant reduction in their psychiatric symptoms with just ninety minutes of moderate-to-vigorous exercise per week. These findings are so numerous and so robust that virtually every neuroscience academic I’ve ever met has a running habit, myself included. You can’t move along the banks of the river Cam without bumping into huffing and puffing scientists.

Studies on the impact of exercise on mitochondrial health are fewer and newer but they are on the rise, and already showing results that are just as convincing. We've discussed some of the links between mitochondria and mood already, but might there be an additional link between them and exercise? It would make sense, since mitochondria are the powerhouses that provide the energy for exercise in the first place.

We know that increasing your heart rate during exercise boosts the rate at which oxygen circulates in your brain, thereby increasing one of the crucial components for mitochondria to turn glucose into ATP. This partly explains why an exercise session can be a great way to prepare for a day of mentally demanding tasks. But as well as the boost to your thinking power, mood and energy, exercise also seems to support mitochondrial health by powering both mitogenesis and mitophagy, which, as we saw earlier, are the processes by which healthy mitochondria replicate themselves and dysfunctional mitochondria are expelled. If you exercise regularly, you're not only bulking up your muscle mass<sup>53</sup> but boosting the generation of new mitochondria<sup>54</sup> to enhance mitochondrial mass. You'll also be helping to prevent age-related decline by improving mitochondria's ability<sup>55</sup> to clear away any defective cells that are no longer operating effectively.

When I asked Martin for his suggestions about strategies to boost mitochondrial health, he stressed that anything that stimulates energy flow will help. 'Any activity that makes you breathe harder, so exercise, for sure, but just getting your steps in, or even having sex, will stimulate your mitochondria. Your brain and body are a kind of predictive system, constantly seeking to be better prepared for the next time an event occurs. If you move hard enough to raise your heart rate and push your breathing, the cells feel as if they're running out of energy; to prepare themselves for the next time something like this happens, they make more mitochondria.'

## *Eating for our mitochondrial health*

What we eat is fundamental to mitochondrial health, and you probably won't be surprised to hear that our familiar foe, the high-sugar, high-fat, highly processed food that many of us indulge in too frequently, is bad for it. Sugary foods allow our cells to perform in a 'lazy' way, relying purely on freely available glucose. If, on the other hand, you reduce your sugar

intake, either through calorie restriction, intermittent fasting or, in a more extreme version, the ketogenic diet that we saw in the last chapter, you're forcing your cells to fire up the mitochondria to extract maximum power from fuel. As Martin Picard puts it: 'Being hungry once in a while is clearly good for your mitochondria. When the body senses that it has less nourishment coming in, it will stimulate endogenous processes within our cells to get rid of things that are working less efficiently, and make more of the things that are working well.'

Mitochondrial processing probably accounts for the fact that hippocampal damage linked to weight gain from a poor diet seems to affect men more than it does women. A study (admittedly on rodents) of hippocampal dysfunction associated with diet found changes to the mitochondrial membrane that indicated poor health in both sexes, but much more frequently in males.<sup>56</sup> As we know, mitochondria are a purely maternal inheritance, so it's possible that female rodents (and humans) have evolved some sort of protective effect that isn't available to the males.

It's probable that part of the impact of the ketogenic diet<sup>57</sup> that Paige and Georgia are following to treat their symptoms is also down to mitochondrial processing. Perhaps they have an inherited propensity for their mitochondria to struggle to clear the build-up of toxic by-products that occurs when their cells process glucose. With a switch in fuel sources as part of the diet, the mitochondria can circumvent the dysfunctional machinery implicated in the chain of processes that burns up fuel, relieving oxidative stress and allowing for a 'metabolic shift' that helps Paige and Georgia to think clearly and regulate their emotions.

But as we've seen, a ketogenic diet is a medical intervention and a serious commitment, so it's reassuring to hear Martin talking about the value of simply eating less sugar, consuming a bit less in general and intermittent fasting (in which you go for 16–48 hours without food). Both calorie restriction (CR) and fasting<sup>58</sup> have been shown to have reliable and robust benefits in the prevention and treatment of several chronic diseases related to ageing, such as Parkinson's, Alzheimer's and neuroendocrine disorders. Studies have found that they increase the rate of both mitophagy and mitogenesis<sup>59</sup>.

In 2020, Assistant Professor Sanaz Mehrabani and colleagues at Isfahan University of Medical Sciences in Iran reviewed the existing data on the

topic and concluded: ‘Current evidence overwhelmingly suggests that CR and fasting<sup>60</sup> induce mitophagy and mitophagy-related markers. Based on the current evidence that we reviewed here, it could be concluded that fasting or CR has a promising role as a novel and practical approach in the prevention of age-related diseases.’ In the same year, Dr Isabella Rocha Dias and colleagues<sup>61</sup> at Diamantina University in Brazil reviewed the last decade of data on calorie restriction on cognition in experimental animals and observed how their ‘findings highlight the potential beneficial effects of CR of up to 40% on cognition when started early in life in non-human animals’.

Fortunately, reducing your calorie intake by 40 per cent is not necessary to reap benefits for your brain functioning and overall health. As Martin points out, ‘Fasting is traditionally a way of preparing the body and mind for transformation, for healing.’ From Ramadan to Lent, to the fasting carried out in Buddhism, Jainism, Hinduism, Judaism and Taoism, the concept of restricting calories for a set duration as part of a group’s religious and cultural practice is widespread. Perhaps our ancestors knew intuitively that fasting was beneficial and that, as a social species, we should encourage one another to do it collectively, for the benefit of individuals and community alike.

## *Sleeping for our mitochondrial health*

Sleep evolved at least 600 million years ago and is highly conserved across the animal kingdom<sup>62</sup> – we do it, worms do it, as do flies and innumerable other species. It takes up around one-third of our existence and, as we’ve seen, plays a huge role in health and cognition. Insufficient sleep has been linked to greater risk<sup>63</sup> of ill health, from metabolic disorders and cardiovascular disease to psychiatric disorders, advanced cellular ageing and cognitive decline. A hypothesis has emerged that one reason<sup>64</sup> we evolved to spend so much time asleep is to keep our mitochondria healthy – perhaps making us slaves, as it were, to the ancient bacterium that invaded our cells many millions of years ago?

In the 1990s, Eric Reimund,<sup>65</sup> a researcher at the Texas Tech School of Medicine, proposed a free-radical theory of sleep, suggesting that ROS

accumulate in the brain when we are awake, when energy consumption is high, and sleep provides an opportunity to clear them in a scavenging process that also suppresses their production. This idea has been finessed subsequently. In 2022, Professor Elena Ziviani<sup>66</sup> from the University of Padova wrote a review suggesting that sleep might also provide the opportunity for mitophagy, which, as we saw earlier, sustains a pool of healthy mitochondria and contributes to the reduction of oxidative stress and inflammation. This nightly mitophagy might also help with adapting to the changing metabolic demand of our cells, which alters depending on our activities and environment. We now know that the metabolic rate during sleep<sup>67</sup> can be reduced by approximately 5 to 15 per cent compared to the rate during wakefulness; energy demands are therefore lower, allowing for clearance of metabolic waste and replenishment of energy stores. In 2023, Richard Richardson and Ryan Mailloux<sup>68</sup> from McGill University in Canada built on this work to advance the theory that sleep arose during evolution in order to protect mitochondria, calling it ‘mitorestorative’. Immune, inflammatory and heat-shock responses can be activated during the sleep cycle to help restock the cellular bioenergetic levels, ready for the next day’s activities and as part of the cellular repair work taking place while we sleep.

This concept of sleep as being fundamentally in service to mitochondrial health was tested by Gero Miesenböck and colleagues<sup>69</sup> at Oxford University, who set out to examine it in fruit flies, which are frequently used as model organisms in the study of basic biological processes and behaviours such as bioenergetics and sleep. The researchers analysed gene expression in both well-rested and sleep-deprived flies, and found that genes that were upregulated after sleep deprivation were almost exclusively those involved in mitochondrial function. They also observed that these changes in gene expression were accompanied by enhanced mitophagy. When they then let the sleep-deprived flies have some recovery sleep, they found that these genetic and anatomical changes were reversed. The researchers then did some reverse engineering to demonstrate that, if they induced or prevented mitochondrial division, altered sleep was the consequence. Their conclusion was that sleep, like ageing, may be an inescapable consequence of aerobic metabolism (using oxygen via respiration to burn fuel). One could take from this that a variety of species,

including flies, evolved to sleep in order to be able to continue to create the high amounts of energy they need the next day.

In 2024, Nahyun Kim and colleagues<sup>70</sup> at Keimyung University in Daegu, South Korea, used the same technique to investigate the link between sleep and mitochondrial health in humans. They recruited 238 generally healthy middle-aged adults and analysed their sleep quality and mitochondrial DNA copy number. Their results indicated that those who reported poor sleep quality (as well as short duration of sleep, difficulty in getting to sleep, use of sleeping medication, sleep disturbances and daytime dysfunction during the previous month) had reduced numbers of mitochondrial DNA in their blood cells. In particular, they found that those people who had difficulty getting to sleep in the first place (longer than twenty minutes) had a lower mitochondrial DNA count and accelerated cellular ageing.

The links between sleep, mitochondrial health and ageing represent a very new area of research, one that is gaining traction rapidly and seems to me sensible and reasonable in terms of its conclusions and implications. I'm doing everything I can to support good sleep for my own health and my son's. This includes the standard advice of keeping stimulation (including blue light) to a minimum in the evening so that our bodies can follow external cues to wind down and prepare for sleep. I try to ensure that we've eaten healthily so that our bodies have enough nutrients and feel sated enough to sleep, while also ensuring that we exercise physically and mentally each day to give our mitochondria their workout. All this with the aim of building up a healthy store of mitochondria ready for their overnight cleaning and replenishment, so we can wake up refreshed the following day.

## *Connecting for our mitochondrial health*

Both Zoltán and Martin stressed the fact that social connection is crucial for maintaining the conditions in which our brains can flourish and we can build our stock of wisdom. Martin has carried out recent work in this domain as the impact on mitochondrial health of positive social interaction is still not well understood, though he's convinced it is important. 'Simple positive interactions with another human being could allow energy to flow through your mitochondria more freely,' he told me. 'There's emerging



evidence that positive psychological states optimize brain and immune system mitochondria for energy transformation.'

He and his collaborator Elissa Epel at the University of California, San Francisco, investigated this concept in a study looking at mitochondria in cells from the immune system<sup>71</sup> and correlating them with mood and psychosocial factors. 'We asked eighty-nine middle-aged women to rate their mood every day for a week,' Martin told me, 'noting how many positive and negative interactions they had with other people, how much love, closeness and trust they experienced, for example. What we found is that on days when women felt more positive, the next day their mitochondria were better at transforming energy. We wanted to understand more about the direction of this influence, whether the mood was influencing the mitochondria or vice versa, so mood was measured every day for a week starting on Sunday. Mitochondria were measured on Wednesday, right in the middle of the time period. This allowed us to ask whether the mood measured on Monday and Tuesday predicted mitochondrial biology on Wednesday, or the mitochondrial enzyme activities on Wednesday predicted how people felt on Thursday, Friday and Saturday. We found a very clear signal. The mood predicted future mitochondria, but the mitochondria didn't predict future mood.'

Martin stressed that 'this is just one study and it needs to be replicated, but the signal was surprisingly strong. These results also align with research from Iris Tatiana-Kolassa in Germany, whose lab has found that early life adversity seems to program mitochondria and change immune cell energetics. In our study, positive experiences and feelings were associated with better mitochondrial energy transformation capacity, negative things with diminished capacity. But the positive effects were stronger.'<sup>72</sup>

These results, along with the findings of the study he and Caroline Trumpff carried out on postmortem brain cells and Barbara Sahakian's study on loneliness and mitochondrial health, have convinced Martin that cultivating positive states of mind, maintaining our relationships and making the most of even small interactions with other people all sustain our energy levels and create positive feedback loops that can help to keep us healthy, happy and smart throughout our lifetime.

# Rethinking energy could power our next evolutionary jump

We opened this chapter by considering the energy cost of thinking, noting that there is a balance to be struck between the body's creation of the energy we need to power our thoughts and feelings, and the avoidance of burnout from the internal pollution that builds up in the form of toxic waste products. The situation is interestingly analogous to the external crisis we face in which the Earth's atmosphere is being polluted by carbon emissions from burning fossil fuels, a predicament that is complicated by our increasing use of AI-driven technology. Machine-learning-based large language models are hungry for fuel in the form of vast amounts of electricity, not to mention the water that's also required to cool the data centres down. (They're also hungry for fuel in the form of human-made content, which many people have pointed out is being taken from its creators without either permission or financial recompense.) AI's cognitive power, like ours, comes at a cost.

In 2022, for example, according to the International Energy Agency<sup>73</sup> (IEA), data centres consumed 240–340 terawatt hours (TWh) of electricity – between 1 and 1.3 per cent of global demand, excluding energy used for cryptocurrency mining. Due to the energy sources they currently use, this accounts for between 2.5 and 2.7 per cent of global greenhouse gas emissions, on a par with or exceeding even those of the aviation industry, at around 2.5 per cent. The issue doesn't seem to be going away. In 2025, the IEA submitted a new report<sup>74</sup> with their updated calculation that all data centres – again excluding mining for cryptocurrencies – consumed 415 TWh of electricity in the preceding year. Dr Alex de Vries-Gao<sup>75</sup> from Vrije Universiteit Amsterdam in the Netherlands has suggested that AI might already account for 20 per cent of that total. In the light of a thorough analysis of the AI chip supply chain, he estimated that by the end of 2025, AI might account for up to 49 per cent of total data-centre power consumption and reach 23 gigawatts, twice the total energy consumption of the Netherlands. 'To be clear,' Alex told me, 'this is increasing much faster<sup>76</sup> than previously expected.'

There are any number of questions about how the global energy system will adapt over the next decade and whether the gains from using AI to

tackle complex problems, including those that concern the climate and ecological emergency, justify its energy expenditure and impact on water supplies and biodiversity. It's a complex issue and there are no conclusive answers as yet to the questions that are increasingly being asked. We must get used to discussing energy efficiency and fuel consumption by information-processing and the clear conflict between the two.

Thinking of our own processing power in this way fascinates me. Are we polluting ourselves to create the energy we need? Is that what ageing is? Or have we evolved to produce our own energy in the greenest, cleanest way possible? (At least if we can give up on poor fuel choices and look after the power-generating system that evolution has presented us with.) If so, and humans are the pinnacle of clean-energy production, what could we learn from our emerging understanding of its mitochondria-driven processing that might inform sustainable energy production for AI?

It might sound fanciful to speculate about ourselves alongside AI in this way, but Dr Picard's understanding of biology makes me think the questions are worth asking. He is convinced that the most important thing we should all take on board at this point in our evolution is that 'a human being is not a molecular machine; we are in fact energetic processes. Science has spent years advancing this bottom-up, molecular, reductionist hypothesis to explain how biology creates consciousness, but I don't think it holds up for many aspects. That's a big problem if we want to understand our deepest nature and what health is.'

I've always been interested in the place at which neuroscience and philosophy meet, which is often at the intersection of what we understand by consciousness, so Martin's ideas set me thinking, especially since they speak to the evolutionary jump that many scientists believe humanity is currently undergoing. In Martin's view, the transformation and deployment of energy in our body is not so much a subsection of our biology, however vital and fascinating, as the basis for a new understanding of life itself, one that we must grasp if we want to maximize our potential.

'The real paradigm shift that's needed in science and in culture,' he says, 'is one that will help us realize that we're made of energy. What you experience as yourself is energy flowing through your brain. If you cut that flow by, for example, blocking your carotid arteries, within seconds you no longer exist. Your consciousness completely disappears. Not because your brain is broken but because energy is no longer flowing through it. We are

all the sum product of the energetic processes that flow through the particular biological structure we inhabit. We eat, and that feeds our energetic processes. We sleep and that changes our energy. We exercise and that changes our energetic state. Once we realize this about ourselves, it becomes easier to understand our relationships as another energetic process in which our respective energies influence each other. Each person is like a little flame of life that can transform another. Tomorrow, I will be a different person because today, you, your energetic process, changed me, my energetic process.'

Could this way of conceptualizing our brain's processing and its reliance on energy provide a new sense of purpose? Perhaps thinking about cognition in terms of energetic processes, fuel sources and pollutants will help us all to use our energy, both internal and external, more wisely to support us as individuals and as a species so that we may survive – and thrive – into the future.

## **|EXERCISES|**

**A brain fit for the 21st century is ... able to accumulate wisdom in a changing landscape**

- Continue to exercise your tolerance of uncertainty and ambiguity and take yourself out of your regular routine by at least once a month trying something new, be it exploring somewhere unfamiliar, meeting new people, discussing new ideas with a new acquaintance or reading a book that broadens your world view. Lean into novelty and the unfamiliar with curiosity rather than fear. All of these new experiences, these challenges, can help exercise your brain plasticity, thereby enhancing creativity, empathy, focus, clarity of thought and your underlying general intelligence factor.
- Optimize your mitochondrial health so that your brain gets all the energy it needs to operate. One of the easiest ways to do this is by eating unprocessed foods rich in protein and unsaturated fat, such as oily fish or avocado, and lots of fibrous vegetables. Reduce or eliminate alcohol, get help to give up smoking and consider taking supplements, including B

vitamins, especially B3 (niacin), B6, B12 and folic acid, alpha-lipoic acid, Coenzyme Q10 and magnesium.

- Daily physical exercise not only enhances your mood but causes your mitochondria to multiply in your body and brain, increasing motivation and your energy production capabilities. Aerobic exercises in particular, such as running or swimming, can enhance mitochondrial efficiency and cause them to reproduce within you, helping you to feel revitalized.
- Starting the day with some gentle exercise, such as a morning swim, can help reduce cortisol's negative effects on concentration. If you find it particularly difficult to focus in the morning, consider strategies to reduce your early peak in cortisol (a chemical that, as we've seen, occurs naturally to create the stress response and peaks with the circadian rhythm, where it is very useful for waking you up but can disrupt concentrated thinking).
- The importance of healthy sleep patterns for longer-term brain health cannot be overemphasized. In the quiet, restful time of sleep, myriad brain activities occur during which what we have learned in the course of the day is consolidated into a stable memory so that this new information can be integrated into our way of thinking and behaving when we wake, allowing us to adapt our habits. Sleep also provides the brain with time to clean away any toxins that have built up during the metabolic activity of the day, for new mitochondria to be created and for any dysfunctional ones to be removed, ensuring that we have enough energy for moving and thinking when the sun rises.

# Global Citizenship and AI

## *Our Healthy Long-Term Partnership*

I WAS SITTING IN A CAFÉ recently, flicking through the newspaper as I waited for my coffee, when an article caught my eye. A team of researchers at the University of Melbourne<sup>1</sup> (partnered with accountancy firm KPMG) had just released the report on their global survey of the public's attitudes towards AI. Between November 2024 and January 2025, they had spoken with 48,340 people, in a representative sample from forty-seven countries, asking respondents how much they were using AI and how much they trusted it. The results were intriguing. A significantly greater proportion of individuals in countries classified as emerging economies regularly use AI. India, Nigeria, UAE and Egypt, for example, top the list, with more than 90 per cent of respondents saying they use publicly available AI tools such as ChatGPT regularly (from daily to once a week). Countries such as the Netherlands, Belgium, Sweden, Japan and New Zealand, on the other hand, come at the bottom of the list with around 50 per cent of people claiming regular use.

The statistics for trust and acceptance track alongside those for use. Emerging economies report a far greater trust in AI than advanced economies (57 versus 39 per cent) as well as higher acceptance (84 versus 65 per cent in advanced economies). India and Nigeria report the highest regular or semi-regular use of AI (92 per cent), and highest trust in it (around 85 per cent). The lowest reported usage was in the Netherlands (43 per cent), but the Dutch were pipped to the post on mistrust by Australians, who rank lowest in the world in their interest in learning about AI and, alongside New Zealand and the Netherlands, lowest on acceptance, excitement and optimism. Only 30 per cent of Australians believe the



benefits of AI outweigh the risks. (The UK and USA sit in the lower quartile of this table, in case you were wondering.)

Other surveys have similar findings. People in the developed world are particularly sceptical about AI's safety, security and societal impact, and they are becoming more so: in 2023, the Pew Research Center reported<sup>2</sup> that, when they surveyed over 5,410 Americans, they found them to be increasingly cautious about the growing role of AI in their daily lives; 52 per cent were more concerned than excited, and that concern rises with higher levels of education. Perhaps it is hope that drives the greater trust and optimism in AI of individuals in emerging economies. A dream that AI will be the tool that helps to level the global economic playing field? Whereas people in the developed world, by contrast, especially the more educated classes who tend to work in the knowledge economy, have absorbed a pessimistic message about what AI will mean for their jobs and their future.

At this stage of AI's journey into our everyday lives, it's probable that you have opinions and feelings about it yourself. You may well use some of the large language models such as ChatGPT for work or study, as a replacement for Google's search function or to turn photos of your kids into cute toddler-kitten hybrids via one of the many image- and content-creation tools. You might be comfortable with or feel threatened by AI. Perhaps it sends a chill down your spine when you read headlines about how it has halved the number of entry-level jobs. Perhaps you are concerned about handing it too much power, given its proven bias or its capacity to undermine democratic elections by seeding and spreading disinformation via social media. Or maybe you're an optimist, hoping it will fix problems, come up with new drugs to treat cancer or ways to make crop yields more plentiful. In all likelihood, you are, like me, ambivalent, feeling a mixture of excitement and curiosity on the one hand, and anxiety and cynicism on the other.

Much has been written about AI's cognitive capacities, about whether it is intelligent, creative, on its way to becoming conscious. There is a whole debate about what it can and can't do, what that means for us and whether we should be afraid, excited or sceptical. There are those in the tech-adjacent world who push the narrative that it's a game-changer for human civilization, and governments and corporations must make it their overwhelming priority to 'win the AI race'. There are plenty of

commentators who decry it as a potentially existential threat to humanity, a cyber overlord-in-waiting, while others have pointed out that it can be really quite rubbish at even simple tasks.

My objective in this final chapter of the book is not to contribute to those debates so much as to explore intelligent ways for us to live alongside this extraordinary new tool we've invented. I want to consider AI as the product of human beings, based as it is on our own intelligence, with its inherent biases, delusions and aspirations. We have made AI in our own image from the outputs of our brains, from the coding used to build it to the writing we train it on and the underlying knowledge obtained from cognitive and computer sciences that have allowed us to develop it.

As a neuroscientist, I find AI fascinating and exciting; as a person, I worry about the way we're using it and interpreting what it means. Sometimes it looks to me like a false promise, the magic bullet that never delivers. I am reminded of the pharmaceutical industries searching for a new wonder drug for psychiatric illnesses, which never appeared. Human beings long for a simple solution to ease our problems and do the heavy lifting for us, and I worry that some of the optimism around AI and neurotech developments will be misplaced if we simply cross our fingers and hope it will solve our intersecting crises. We cannot afford not to understand what's at stake, to deskill ourselves through over-reliance or sidestep the necessary hard thinking about how we want this powerful tool to be used. After all, dominance in AI is the glittering economic prize of our time, not to mention a potential military weapon and an unprecedented form of cultural influence. The world's most powerful people have a stake in what happens next with AI, and that makes me aware of vulnerabilities in how it is developed and may affect our lives.

But the part of me that is awestruck by AI's potential is resistant to pessimism. I return to what I know about humanity's cognitive powers and I feel sure that these technologies are part of our evolutionary story, but not its end point. AI is our tool and we would do well to treat it as such and try to relate *to* it and engage *with* it intelligently, with calm and curiosity rather than fear or anthropomorphizing. I believe our human skills of listening, turn-taking, empathy, a sense of enquiry, awe at the world and feeling motivated to innovate are powerful. Instead of leaning on technology as a crutch, alternately idolizing or demonizing it, I believe we should lean in to our very own intelligence that has evolved over countless millions of years.

As I hope I've shown you, our skills are extraordinary and we must cherish them for our own sake as well as future generations' and our species' long-term success.

Let's start by looking at what AI tools already enable us to do, their strengths and limitations. I spoke to an inspiring tech pioneer who's using a form of AI that has trained in what he calls the 'language of biology' rather than a natural language such as English, to uncover already approved drugs that could be repurposed to treat rare illnesses. That conversation reminded me that AI reflects ourselves: our priorities and our blind spots. It's only as game-changing as the ways in which we craft and deploy it.

I also spoke to a specialist in neuroscience and philosophy for his take on AI, consciousness and creativity, and came away more than ever convinced that the smartest thing most of us could do in relation to AI is to play with it. Only through open-minded use and trial and error will we grow to trust our own powers and start to believe in AI as a partner and ally rather than a threat or a panacea. The more comfortable we are in this position and the less we defer either to AI itself or to the powerful people who want to wield it for their own gains, the better.

My objective is always to turn our questions back to ourselves. How can we interact with AI and other technologies to deploy them in our best, most human-centric interests? Are we going to settle for creating porn deepfakes and videos of the (admittedly highly amusing) Olympic cat-diving competition? Given that AI is already being fed copious water, electricity and the work of millions of human beings to sustain itself, and that it will continue to reshape our environment and our brains, it seems important to continue to push for a serious discussion about how to use it in a smart way. That might lead us to conclude that some regulatory framework is necessary, not to rule out deepfakes (much less cat videos), but to try to anticipate ways in which it could be used to inflict harm.

We're entering a time of great uncertainty and major upheaval. The impact of this technology is unknowable. We will need all our mental agility, curiosity, empathy and calm in the face of uncertainty to make the most of its benefits and steer it in a direction that aids our collective flourishing.

## Where are we now?

Given our species' drive to explore new spaces and ideas and to communicate our discoveries, it is perhaps no surprise that we have developed the technologies that are currently opening our eyes to new possibilities. AI's powers of analysis are almost unimaginably vast. It can comb and dissect interlinked data sets at exponential speeds, much faster and with much greater accuracy than could be achieved even by a group of expert humans. It can make connections and detect patterns that are literally invisible to the human brain. This allows for a depth and breadth of innovation that, in some cases, may add up to a reshaping of reality.

Back in 2019, for example, AI was used by scientists<sup>3</sup> including Professor Regina Barzilay and Dr James Collins of MIT to discover a new antibiotic that proved effective against bacterial strains previously labelled resistant. The AI model was trained on a data set of approximately 2,500 known molecules, including 1,700 previously FDA-approved drugs and 800 natural products, and asked to learn to recognize which attributes were antimicrobial. It then trawled through a library of 6,000 compounds. Its goal was to predict whether any of these might be at once effective, non-toxic and different from existing antibiotics. One molecule fitted the brief and was named Halicin, in a nod to the AI computer HAL in the 1968 film *2001: A Space Odyssey*. It has now been developed into a new antibiotic that is being used successfully with patients whose conditions would previously have been untreatable. This was an impressive achievement for AI and important medically, but what really stands out to me is that researchers were initially unable to explain exactly how and why the molecule works. Its entirely novel mode of action, involving the disruption of the bacteria cells' ability to maintain an electrochemical gradient at the membrane, meant not only that it wasn't a candidate drug but that the scientists struggled to account for its effectiveness. AI appeared to be able to perceive some hidden feature of the molecule that was simply imperceptible to humans.

Achievements in this field have developed exponentially since 2019. In June 2025, I spoke with a former colleague from the University of Cambridge, Tim Guilleams, who has founded a company called Healx<sup>4</sup> to develop drugs for rare illnesses with the help of AI. His team use a tool that has been trained in the language of biological data to comb databases of molecules, search for patterns and build signatures of diseases and develop the drugs to tackle them. Healx's first success came with the discovery of a

molecule that has proven to be effective against a very rare form of cancer called neurofibromatosis type 1 (NF1), which causes tumours of the nervous system and on the skin. People carrying a specific genetic mutation are susceptible and typically begin to develop symptoms around puberty that become severe by late adolescence. Tumours are initially benign but can become malignant at any time and cause severe pain and disfigurement. In the past there has been no cure, and only invasive and ineffective treatment via toxic cancer drugs. Patients have a reduced life expectancy, having endured a poor quality of life for years. NF1 is a very nasty condition but because it affects such a tiny number of people, there has historically been less commercial justification for the years of intensive research and development needed for breakthroughs. This is true for many rare diseases, which often see slower innovation due to smaller markets.

That all changed with the advent of highly sophisticated AI capable of accelerating the research process. Tim and his business partner, Dr David Brown, founded Healx way back in 2015, and in 2019 launched a new AI program targeting NF1. The work has now yielded what Tim describes as ‘possibly the world’s first targeted cancer drug<sup>5</sup> for NF1 that has no side effects. We used AI to search for a drug that’s safe, that targets nerve cells, and has anti-tumour properties. We found it.’

Tim stresses that without AI’s incredible capacity to work at scale, this would have been impossible. That is still the case in much of the pharmaceutical industry, whose standard model is ‘target-based drug discovery’, which aims to find the one drug that will prove effective for patients. The problem is that, 95 per cent of the time, the target drug that was identified in a lab ends up failing in clinical development. ‘The foundation for Healx,’ Tim told me, ‘was to start in a target-agnostic, hypothesis-free way. We analyse a lot of biological data, the genome, proteome, metabolome, transcriptome, looking for patterns, and then we let AI generate complex disease signatures based on the analysis of about a billion molecules. We don’t intervene. Then we let AI predict which molecules will reverse that disease pattern to a healthy one. Often we don’t even understand the drug–disease matching signature and rationale at this point; we just send the best-ranking molecules to the lab for testing. And for those molecules that work, we then reverse engineer the biology until we do understand it.’

Tim and his colleagues began this process for NF1 in 2019, and in 2024 they received the green light from the US Food and Drug Administration to start clinical trials, which was much faster than the industry standard of ten to fifteen years. Now they have five young patients taking the drug and are getting ready to expand its use. (Somewhat to my amazement, Tim told me that the molecules AI identified as the basis for the drug attack the mitochondria in cancerous cells, eventually killing the tumour. Mitochondria seem to be a running theme in much of the most pioneering work on health in the twenty-first century.)

Tim's delight at the game-changing, human-centric potential of this AI-powered work was infectious. 'We think it offers a paradigm shift for patients and their families. Rather than waiting until you have a hundred tumours across your entire body before you're forced on to toxic cancer drugs for the rest of your life, you have a chance of a tumour-free, symptom-free, pain-free and potentially much longer life. I think there's a lot of potential with other cancers that affect nerves, and other diseases as well. We've found something new here.'

If all we were doing with AI was allowing experts to use it to scan huge data sets to develop drugs for rare diseases, there would be fewer questions over its relative value; but of course that's not the case. Use of AI is not confined to university science departments and biotech companies; nor should it be. It's embedded in recruitment processes and facial-recognition techniques used by security services; in virtual assistants, search engines, digital marketing and social media. OpenAI has indeed made at least the basic version of its tool freely available to all. AI is now everywhere, and while it is better than human beings at some cognitive tasks, it's no better than us at many others. In fact, it replicates our cognitive blind spots, unsurprisingly since it was built on neural models derived from our own brain circuitry and human-produced words and images. That ensures that one of its big cognitive limitations, like ours, is bias.

When I spoke at TechFest 2025 in Cork in Ireland, I met Jonathan McCrea, broadcaster and founder of the training company Get Started with AI. Jonathan talked about AI's difficulties with bias and stigma by referring to an incident concerning one of his colleagues, who had used a publicly available AI tool to adjust a photograph of herself speaking at a conference, before uploading it. She asked the AI tool to 'tidy up' the photo, and specified that it remove the coffee cups on the table in front of her, which it



did. It also changed her into a man, totally unasked. Having consulted its data, it assumed that a speaker at an event like this would be a man, and accordingly wiped her out without even realizing it had committed an error. Jonathan stressed that this had happened with an earlier version of the AI model, and that LLMs are improving all the time. Making such an obviously biased unprompted decision probably wouldn't happen today, but many other harder-to-spot biased assumptions are still being built into AI's processing. The anecdote neatly illustrates the point that AI replicates many of our cognitive flaws and, just like us, is not necessarily even capable of noticing them.

AI can course-correct for bias in the same way we do, by taking on multiple different perspectives. In theory it should be good at that: finding data from a different source and adjusting accordingly is the work of a nanosecond for an LLM. But of course, without any agency of its own, it needs direction from us to do so, direction that is sometimes lacking. That means it can end up being far more biased than a human being.

A study by researchers at the University of Delaware<sup>6</sup> published in 2024 in the journal *Scientific Reports* set out to examine the levels of bias and the prejudiced outputs produced by LLMs as they go about their work. The team fed just over 8,000 headlines from Reuters and the *New York Times*, which they had determined to be the least-biased news sources in the US, to a number of different LLMs including Grover GPT-2, GPT-3 and ChatGPT. They then asked the AI systems to write a piece to fit each headline and compared them to those written by human journalists. The focus of the study was on sexism and racism. What they found was that the AI systems produced writing that was loaded with prejudice and an entitled sense of male, white hierarchy. Approximately 40–50 per cent of AI-written articles contained sentences with instances of these biases, with sexism and racism occurring at a roughly similar rate.

It would of course be unfair to blame AI for this: it was only replicating material culled from the vast trove of human-produced writing it had been trained on. Comparing its outputs with those from some of the most trusted outlets in the world nevertheless shows us that bias is inherent in the way AI 'thinks' because it's inherent in the way most of us think, unless we're making conscious efforts to correct it through exercising our own critical thinking and taking on other people's perspectives. A piece published by Reuters has passed through the hands and brains of many different people

before it goes out, all of whom have been set the goal of avoiding bias and adhering to an editorial policy. The hive mind represented by a respected media organization knows that it needs to be vigilant and has systems in place to catch errors and assumptions. They won't always work, but they seem to work well enough to filter the pieces they publish to catch many of the unforced errors and biases that plague AI.

How can we design and train AI to be less biased? By requiring it to consult the hive mind in a deliberate way. Our species' success derives in large part from our collective intelligence: the combination of many different perspectives with a socially agreed way of communicating them via language. Formed by our genes and individual experiences, we each have a brain with a unique perception of the world, and with unique strengths and idiosyncrasies. This diversity of thought creates a deeper collective cognitive pool. Neurodiversity brings cognitive strength to society, as well as to the data that we're feeding AI. I think current LLMs reflect the fact that we are not yet incorporating that diversity of thinking into our ways of working to anything like the necessary extent. AI will continue to develop in whichever direction we set for it: wherever our attention is focused. It is a mirror for society's preoccupations, reflecting our success stories and flaws, our values, how we represent ourselves, how we listen to each other and either promote or sideline the different ways of thinking of which our species is capable.

## Reshaping our reality, for good or ill

Humanity has of course lived through periods of technology- and knowledge-driven change before. Often, society absorbs the impacts of innovation with only minimal adaptation, but some of our inventions reach so far into our systems of thought that they propel a complete reshaping of the environment, both in the external world and within our minds. Think of the printing press, for example, and the way it hastened the democratization of knowledge.

Innovation on this scale is both exciting and messy. It will have far-reaching consequences that are impossible to predict at the time of its invention and early adoption. The theory that the invention of the printing press, for example, was a key driver of the Protestant Reformation and the subsequent deaths of millions in the wars of religion, not to mention the rise

of humanism and capitalism, has been widely advanced by economic historians.<sup>7</sup> The precise chains of cause and effect are hard to disentangle, but there's no doubt that the printing press was hugely disruptive precisely because it occupied a connecting space between tech and thought, allowing ideas to jump from mind to mind with relative ease. AI is clearly in the same category as a harbinger of upheaval, just like the internet before it and on which it depends.

Game-changing innovations that alter the reality we swim in cannot be categorized as either positive or negative because, by definition, their impacts are too various and complex for a simple binary assessment. Parallels can be similarly tricky to make, but over the last few years, many people have, as we saw in [Chapter 3](#), made the connection between the creation of the atomic bomb and AI, how each has reshaped global politics, economics and culture, and each has the terrifying potential to be misused. There are at least as many divergences as parallels, though, and I am not a tech-alarmist, merely sceptical and cautious. What's certain is that while AI may not be an existential threat on the scale of nuclear weapons, it does pose grave challenges to the way our minds operate. It can be used to covertly manipulate them, en masse.

In 2014, Adam Kramer, a researcher at Facebook,<sup>8</sup> conducted a massive undercover experiment on about 680,000 of the social-media platform's users, altering how they received and consequently shared news stories. He demonstrated that if he changed the content of an individual's newsfeed by covertly tweaking the algorithm to dial up negative stories and dial down positive ones, for example, the emotional state of that person would then be spread to others, each sharing content of a similar tone, in a process of digitally enabled emotional contagion. This research was published in the well-respected journal *Proceedings of the National Academy of Science* but has since been heavily criticized for its unethical experimental design in manipulating people's emotions without their consent. While highly suspect in its methodology, the study clearly demonstrated how easy it was to alter and disperse an emotional state among individuals, with what was at the time still a relatively new social-media tool.

In the same year, a much more notorious Facebook-centred scandal<sup>9</sup> was brewing. Cambridge University academic Dr Alex Kogan had been harvesting the personal details of Facebook users via a personality app he

had developed for his research. While the initial core group of several thousand app users had agreed to their data being used in an academic study, the app also took data from their friends' profiles, without their permission. In the end, approximately 87 million people had their data passed to Cambridge Analytica – a commercial political consultancy firm that described itself as a specialist in 'global election management'. It was partly owned by various donors to the Conservative Party and the American hedge-fund billionaire Robert Mercer, among others, and headed at the time by Donald Trump's key adviser Steve Bannon. A system was then built that could profile individual US voters to target them with personalized political advertisements, which was deployed throughout Trump's presidential campaign. It was also used by the campaign group Leave.EU during the UK's Brexit referendum campaign.

It no longer feels surprising that our ability to communicate with one another 24/7, across the globe and with few constraints on content, might impact how we think and feel about things. In the wake of various scandals, it doesn't even feel surprising that certain individuals would seek to manipulate that process in an underhand way. What does feel novel is the exponential potential for manipulation that occurs when AI's content-creation skills are combined with social media's reach. This mega-technology can be used to reshape our core values and belief systems, without our awareness, as another suspect AI-powered experiment demonstrated in 2025.

On 2 May 2025, the *Atlantic* ran with the headline<sup>10</sup> : 'The Worst Internet-Research Ethics Violation I Have Ever Seen', followed by 'The most persuasive "people" on a popular subreddit turned out to be a front for a secret AI experiment'. Researchers from the University of Zurich had covertly used the 'Change My View' subreddit (r/ChangeMyView), a 3.8-million-user community built to explore changing minds through open debate, as the space to study how AI could be used to manipulate people's opinions. They set bots to analyse users' post histories to infer demographics such as age, gender, ethnicity and political orientation. The researchers then used multiple accounts to deploy AI-generated posts with thousands of comments. Accounts adopted personas such as abuse survivors or controversial identities, including an anti-Black Lives Matter advocate. The experiment was allegedly conducted without Reddit's knowledge, with the apparent aim of assessing the persuasiveness of LLMs

in an online debate about ethical questions. At the time of writing, the university has not disclosed the identity of the researchers or their departments for privacy reasons, while they investigate, but it has said that the team behind the project had decided ‘of their own accord’<sup>11</sup> not to publish the study’s results. Meanwhile, Reddit’s chief legal officer, Ben Lee, has stated that the company intends to ‘ensure that the researchers are held accountable for their misdeeds’<sup>12</sup>. There are multiple ironies attached to this episode. Did the investigating team believe that their goal of showing how easily people’s minds can be manipulated by AI justified their own greater manipulation? After all, AI did not decide to infiltrate this subreddit; humans did.

If AI can demonstrably be used to manipulate our thinking, emotions and core beliefs, then it is evidently a potential danger to individuals and groups, to civil society and democracy. But as Tim Williams’s work at Healx shows, it’s also a literal lifesaver. Can AI be deployed to help solve our global challenges? The answer is clearly yes. Whether we will choose to do so is a much harder question to answer in the affirmative, and in the meantime the risks and drawbacks posed by AI mount up. As we saw in the previous chapter, when it comes to addressing our existential carbon-pollution problem, on balance and as currently used, AI is probably contributing to rather than solving the problem. That may of course change. Consultancy firm Morgan Stanley identified generative AI’s accelerating energy needs<sup>13</sup> (70 per cent growth year on year between 2024 and 2027) as having *the potential* to drive the power sector’s decarbonization efforts and boost the pace of the global transition to clean energy and storage. Somewhat less optimistically, though, Morgan Stanley also predicted that AI’s energy requirements will account for up to 40 per cent of the USA’s carbon emissions by 2030. As yet, nobody knows how this scenario will evolve. It’s an understatement to say that there is all to play for.

When we use these incredibly powerful resources in a flippant way that hurts rather than helps our species, I can’t help but worry about our prospects of working with AI with long-term thinking front and centre. Asking a chatbot to ‘make me an action figure’ or ‘use AI to rate how attractive I am’ concerns me, precisely because such requests are so much more energy-demanding than searching for cute cat videos on YouTube. Estimates suggest that each ChatGPT query<sup>14</sup> uses approximately ten times

the electricity of a standard Google search. And generating a single image with ChatGPT can consume 2–5 litres of water for server-cooling alone. I'm not convinced that using AI tools to massage our egos is the way forward for humanity.

I believe a debate about how we as individuals use AI is important, not least in this context of the pollution that will otherwise remain out of sight, but I would never suggest that individual use should be subject to oversight via international mandates. I think differently, however, when it comes to the use of AI by the likes of universities, commercial companies or political campaigns. This is too powerful a technology to allow it to escape from an ethical framework embodied in legislation. Otherwise, we will remain open to mass manipulation by those that choose to use these new developments for their own gains.

Then there are the questions posed by the 'what if' scenarios around whether AI will attain a general intelligence and become effectively conscious and independent of us. We'll return to this in a moment, but for now AI safety campaigners are already calling for an existential-threat assessment akin to the calculations made before the first nuclear test. On 10 May 2025, the *Guardian* reported<sup>15</sup> that Professor Max Tegmark, a physicist and AI researcher at MIT, had just published a paper on a series of calculations that he and his team had carried out to assess the risks to humanity posed by a highly advanced AI system. Tegmark has been campaigning for safety assessments of AI and an ethical framework around its development since 2014, when he co-founded the Future of Life Institute, a non-profit organization that works to 'steer transformative technology towards benefitting life and away from extreme large-scale risk'. Just after the release of ChatGPT in 2023, the institute co-published the open letter<sup>16</sup> that called for a six-month pause in building more powerful AIs. As we've seen, the pause never materialized. Tegmark consequently decided to attempt a similar exercise to the one carried out by physicist Arthur Compton before the Trinity test when, following concerns raised by Oppenheimer, he calculated that detonation of a nuclear weapon would not set fire to the atmosphere and thereby endanger humanity, thus clearing the way for the Allies to bomb Hiroshima and Nagasaki. In terms of the threat to humanity, Tegmark's team reached a different conclusion, however: they calculated<sup>17</sup> that there was a 90 per cent probability that an



all-powerful super-intelligent AI would be created that could escape human control. It's reassuring, however, that in May 2025, the Singapore Consensus on Global AI Safety Research Priorities<sup>18</sup> was agreed by a group of academic and industry leaders, including figures from OpenAI and Google DeepMind. Even so, the risks remain alarming, especially given the pace of change.

I think we all need to be concerned but also curious and calm about the development of AI. Numerous experts advocating for its human-centric development are formulating useful conventions around their work, such as the Singapore Consensus. The wider and more informed the general conversation, the better. As Tim from Healx put it to me, it may well be that at some point 'governments will have to intervene to put in guardrails because some people will use it for good, and some people use it for bad'. I believe we have a part to play in petitioning governments and companies for sensible international regulations while adopting best practice in our own personal use of the tech. We can inform ourselves about its risks and benefits, weigh up whether our own use feels proportionate and use critical thinking to ask questions as its development continues apace.

## AI and creativity: what can we learn about consciousness?

That accelerating pace of change poses a serious cognitive challenge to us humans, and its difficulties range from the philosophical to the practical. It's hard to anticipate how these technologies will evolve and what that will mean for our future when the field is moving so quickly. This has been the case throughout the development of AI, as Dr Raphaël Millière, Associate Professor in Philosophy at the University of Oxford, explained to me. Raphaël's working day is spent deep in the thickets of theory on human and artificial intelligence. He also finds himself fielding students' anxieties about which career choices will offer a degree of protection from being replaced by AI. 'Truth be told, it's hard to give a confident answer,'<sup>19</sup> he told me. 'Human beings have been consistently wrong about what AI will and won't be able to achieve. This has become known as Moravec's paradox [after the computer scientist Hans Moravec who first articulated it], which says that activities we find intellectually demanding, such as chess,



mathematics or essay-writing, have turned out to be easier to automate with AI than anyone predicted, and vice versa: seemingly trivial human activities have proved the hardest to automate. In the 1950s and 60s, for example, AI researchers thought that sophisticated chess play was the pinnacle of human intelligence. And then Deep Blue beat Kasparov and we realized that strategic game-playing doesn't require the kind of intelligence we thought it did. Making a cup of coffee or folding laundry, on the other hand, tasks that a human being finds very easy, are extremely difficult for a robot to perform. They rely on perception and sensory motor skills, which contrary to the slightly chauvinistic and blinkered beliefs of those 1950s researchers, involve challenges that can't easily be solved simply by adding more processing power.'

Having established that humans have a poor track record in predicting how AI will develop and how our relationship with it will evolve, Raphaël was generous enough to help me think through one key aspect of the knotty problem. Creativity has always underpinned humanity's flourishing, along with our ability to work as a group, plan for the longer term, pause and reflect, and use our energy wisely for clear thinking in an uncertain world. Interestingly, these are precisely the skills that AI engineers are increasingly turning their minds to in the era of increasingly powerful computational technology and AI.

Creativity is, as we saw in [Chapter 2](#), one of the buzziest arenas for cognitive scientists. Everyone from researchers to teachers to recruiters agrees that it's key to our ongoing success on both an individual and collective scale. If we understand creativity as *innovative problem-solving*, there's no doubt that AI can be highly creative and hugely useful, as breakthroughs in the field of drug research have proved. But if we think of creativity as a form of self-expression, of the agency of an individual who chooses to try to convey something of their unique perspective, then questions about AI's creativity arise. AI can undoubtedly do pattern-spotting and divergent thinking better than us. It can even discern aspects of reality that are invisible to our brains; but without a biological brain of its own, can it mind-wander? Its outputs might be superficially compelling, even prize-winning, but are they authentic creative acts?

Raphaël specializes in language processing and reasoning. He pointed out that an LLM can definitely do novelty, generating 'brand new sentences that have never been written before in a way that's not straightforwardly

relatable to any snippet from the training data. But when people talk about creativity, they're often concerned with a more demanding notion, which is connected to agency. An artist has an intention to create something and a vision for their work. Current generated AI systems have no intrinsic desire to create something; they're just reacting to prompts.'

This might feel more conclusive than it really is, as Raphaël went on to help me grasp. As we talked about originality, agency and intention, he told me about visiting an exhibition in Paris on Picasso's relationship to the Old Masters. Picasso, like many other artists, was inspired by Velázquez's paintings and created pieces that were somewhere between homage and quasi-plagiarism. As Raphaël observed: 'Some of them were not very original in the dictionary definition sense, but most people would probably agree that they represented a creative exploration born out of a particular impulse. If an AI system had created these very same paintings, would we be as willing to describe them as the products of creativity? I'm not sure. I think we would assess them as an unoriginal product rather than the end point of a creative process.' In this way of thinking, the positive score ascribed to human agency trumps the negative one ascribed to pastiche in a way that is not available to AI, lacking as it does the capacity to conjure up an idea from the urge to create.

I take a different view, one that blurs the distinction between man and machine and their respective creativities. We now know that human beings are biologically 'pre-programmed<sup>20</sup>' to behave in particular ways by the genes we inherit from our parents. As we saw in [Chapter 2](#), there is a significant heritability to creativity; some of us are simply more predisposed to it than others. Such people are highly motivated to create and they experience hyperfocus, or flow, as they're acting on that urge. If Picasso was pre-programmed to be creative by his DNA, surely that's similar to the way we program AI to behave creatively? Perhaps the prompts we give AI are analogous to the prompts Picasso took from his environment and the inspiration he derived from exposure to the paintings of the Old Masters?

When we talked more about agency or autonomy and how it relates to creativity, Raphaël and I found ourselves thinking about children. As we've seen, alongside the variation in creativity between individuals, there's also an observable trend for most people to be more creative as children and lose that capacity as they age. Raphaël pointed out that here is another

interesting link with agency and autonomy. ‘Children have an innate creativity but a toddler hasn’t yet lived long enough to have a sense of their own identity. So one might wonder what differentiates AI systems from creative children, since parents or caregivers are instructing [the latter] and shaping their behaviours and outputs. I think one important difference has to do with a child’s internal motivation to play, which is a way of exploring and expressing curiosity. It’s not to do with autonomy as such, because a baby has virtually none. Compared to a lot of other juveniles, human babies need constant care. But they also engage in play and exploration pretty much from the moment they’re born. Even neonatal infants will grab their feet and gaze around. That active engagement is lacking from current generative AI systems. You can’t release an LLM or an image-generating system in a virtual environment and watch it go, because it can only react to prompts. There is no active exploration. Interactivity is key to the creativity of a biological organism, especially a human child. They engage with the world; they’re not purely reactive, not purely passive. They may not be autonomous but they are curious and very exploratory; there’s a lot of agency there.’

At this point I was making a mental note to myself to try *not* to curb my nine-year-old son’s strong-willed sense of agency and limitless curiosity quite as much as I inevitably do when we’re rushing to get to school on time. If that’s what sets him apart from AI, then perhaps I need to find more ways to build slower-paced unscheduled exploration into his life. Or better still, given that it will benefit my ageing brain just as much as his developing one, into both of our lives.

This conversation with Raphaël made me question whether our current educational systems are equipped to cope with these vast technological shifts. Why is there so much emphasis on learning by rote from a young age, rather than making time for exploratory play? Why are we still encouraging more students to opt for STEM subjects rather than humanities, when AI can and will fulfil their functions more efficiently than humans can? Of course we will always need human scientists and engineers, but far fewer of them than in the past. This feels to me like an error that’s analogous to the one the pioneering AI scientists made back in the 1950s when they assumed that chess would be hard for robots and folding laundry would not. (Although, given Moravec’s paradox, perhaps I

would do well to check my own thinking for blind spots in the form of bias and hubris. Future-proofing my own cognitive skills requires nothing less.)

This conversation about the neural circuits that creativity depends upon in humans and AI prompted me to consider what other kinds of thinking we might intelligently ask AI to assist with, and which we would do better to keep working on ourselves. When we repeatedly ask a machine to take on a cognitive task for us, we eventually deskil ourselves in that task. That may be a fair trade-off, or it may not. Calculators, for example, are much better at complex calculations than most humans, and so long as some of us continue to train to be theoretical mathematicians, perhaps it doesn't matter if most of us are merely numerate. If Google Maps is reliable and efficient and so long as some of us still train to navigate by charts, perhaps it doesn't matter if most of us are not as good at getting from A to B without the satnav as we used to be.

We will always need some human experts in every field to ensure that AI does not outskill us in any area. The difficulty comes in knowing which skills will prove critical. One that we cannot afford ever to give away to AI is, precisely, critical thinking: the ability to assess new data and compare it with lived experience, or to compare multiple data sources and think hard about their relative value and their contribution to meaning. As Raphaël observed: 'When it comes to offloading our capacity for critical thinking, I do worry about how we mature as individuals, as a matter of personal development, of the richness of our inner lives or our capacity to consider ethical questions. A lot of people in tech, for example, think you can solve any ethical issue related to AI in a purely technical way. I think that's a very myopic way to think of societal issues and that you can't just brute-force your way through them. There is a widespread and very condescending dismissal of the relevance of history, philosophy, sociology and literature in the tech world. It seems to me that the value of philosophy, for example, is to think through it yourself. If you let an AI churn through the works and come up with some conclusions, you won't have done any of the thinking yourself or figured out how it applies to your own situation. In the same way, if you want to write a novel, you wouldn't ask ChatGPT to do it for you because the value to the writer comes from the creative process itself. It's as absurd as it would be for a high-level athlete to enlist a robot to run for them.'

A reader may of course not care whether the novel was written by a human or an AI system, if the latter has done a good job at producing a sufficiently convincing imitation of a novel, but for the writer, it would miss the point entirely. An LLM might provide a speedy and efficient way to get a book written and possibly even published, and that book may or may not be a good read, but if the writer's goal was to learn how to write a book or discover how it feels to write one, the LLM would be unable to help.

As Raphaël pointed out, there is a tension between productivity-driven efficiency, which depends on fast thinking, and the value of slow-paced exploration. As we saw earlier in the book, when we wrestle with ideas rather than immediately rushing to conclusions, the gains can be greater. This is something that engineers are currently trying to replicate in AI, as a way of reducing error and bias and ensuring greater saliency. There is much to be said for a cognitive system that can slow down and think through a problem before producing an answer. OpenAI's o1 system, which was released in September 2024<sup>21</sup>, was developed to answer this need and represents another step in the evolution of language models. The fact that it has proved considerably harder to train a system to operate in this way only serves as a reminder of the richness of cognitive skills available to humans.

When I spoke to Geraldine van Heemstra, the artist we met in [Chapter 2](#), about her take on AI's capacities, she had a refreshingly simple and human-centric response. Geraldine, as we saw, has an unusually high capacity to generate visual imagery in her mind, so perhaps it's no surprise that she enjoys using physical maps and remembering routes rather than delegating navigation to Google. 'I think we numb ourselves when we rely on technology<sup>22</sup> to complete tasks, even the simple ones. I feel a bit empty when I use Google Maps. There's something enriching about looking at a map and planning and remembering my route ahead of time. I get so much more joy out of it.' Learning to navigate the world without technology feeds our capacity to explore, imagine different scenarios and figure out what we want to create. There can be few more fundamental human skills, and as Geraldine reminds us, few so joyous.

## Brain-machine interfaces and brain coupling

Professor Kevin Warwick of Coventry University,<sup>23</sup> a cybernetics engineer and pioneer of AI and robotics nicknamed ‘Captain Cyborg’, has been experimenting on himself as well as in the laboratory for nearly thirty years. Since 2002 when he chose to undergo a two-hour surgical operation to insert a ‘brain gate’ system, linking nerves in his arm with a computer so that he could turn lights on and control a wheelchair via the implant, he has been pushing at the fleshy boundary between human beings and robots. He was frequently sidelined as a maverick but the world has caught on and caught up. Brain–machine interfaces are becoming routine in therapeutic settings. Cochlear implants allow babies who were born deaf to hear and go on to speak. Bionic legs give amputees continuous neural control over their new limbs; there is even a hippocampal prosthetic in development that will help with memory encoding and recall for people with Alzheimer’s.

This may sound like the stuff of science fiction but prosthetic brain devices have in fact been around for decades. Deep-brain implants can be used to treat numerous conditions, including Parkinson’s disease and severe depression. The fitting procedure involves drilling into the patient’s skull to implant thin metal electrodes into specific brain regions. These electrodes, or ‘leads’, are then connected, via a meticulously placed wire extension, to a very small neurostimulator, similar to a heart pacemaker, implanted under the person’s collarbone. Continuous pulses of electric current from the neurostimulator pass through the leads and into the brain, changing the patient’s brain activity and altering their behaviour. My neighbour Kate has had one of these deep-brain implants fitted, to help switch off the tremors caused by Parkinson’s disease. She now links up the brain implant with an app on her phone, and can increase or decrease the electrical current at will, to control her symptoms.

While these techniques are becoming ever more sophisticated, there are still significant hurdles, as Professor Jia Liu, a bioengineer at Harvard University, explained at a conference, held in Shenzhen, China, in early 2024,<sup>24</sup> to discuss cutting-edge neuroengineering developments. One fundamental issue is that the brain is very soft, in contrast with the rigidity of electrodes, which can drift due to small movements or trigger an immune response from surrounding brain tissue. Consequently, Jia is developing a flexible-mesh electronic probe that he hopes will reduce the risk of drifting and immune responses. Current brain-stimulation techniques also require complex surgery to implant and connect multiple components using long

wires. Professor Jacob Robinson, a bioengineer at Rice University in Houston, Texas, has developed a pea-sized device that is powered wirelessly via an external transmitter. It stimulates the brain through the dura (the protective membrane attached to the bottom of the skull) by converting magnetic fields into electrical pulses, enabling wireless-powered delivery and eliminating the need for batteries.

The latest deep-brain-stimulation devices are being trialled to treat a variety of complex conditions, including depression, obsessive-compulsive disorder and addiction, and AI is used to help assess their effectiveness. Unlike the visible improvements in tremors seen after successful treatment of Parkinson's disease, clinicians working with patients with psychiatric disorders must rely on changes in self-reported symptoms, which can be difficult if the conditions are associated with a blunting of emotions or altered sense of self. At the Shenzhen conference, Dr Christopher Rozell, a computational neuroengineer at Georgia Institute of Technology in Atlanta, described a new type of brain-stimulating device that can simultaneously emit impulses and monitor the local neural response, to see how the circuits surrounding the implant are responding. AI can then trawl through the vast data sets collected from surrounding brain cells to help assess whether the device is delivering measurable improvement. Christopher reported that he and his team<sup>25</sup> have successfully implanted the new device into ten patients with major depression for a six-month period, and used AI to identify changes in neighbouring neural activity that might indicate depression or recovery, and even predict relapses.

As well as brain-machine interfaces, brain coupling is rapidly gaining traction. In 2019, a team of researchers from the University of Washington<sup>26</sup> and Carnegie Mellon University introduced 'BrainNet', a system that connected the brains of three individuals and allowed them to jointly carry out a simple cognitive task without any direct communication. Information derived from EEG data analysis of the two senders' brains was transferred via the internet and delivered through magnetic stimulation of the receiver's occipital cortex, allowing the receiver to understand which decisions the senders had taken and respond accordingly. A second round of the game then allowed the roles to be switched and decisions and responses to be transmitted in the reverse direction, allowing for mistakes to be checked and rectified. That breakthrough invention, which the team described as 'the first multi-person non-invasive direct brain-to-brain



interface<sup>27</sup> for collaborative problem-solving’ in the world, has paved the way for the development of an interconnected human super-brain. As our technologies and imagination for what is possible continue to expand, might we one day enlist millions of brains to work together as a ‘biological computer’ to tackle questions that could not be posed, let alone answered, in any binary form?

Although these developments hint at profound potential, they also raise concerns about privacy, intellectual property and autonomy. How far will we go at fusing electronic chips with our brain cells in an attempt to enhance our cognitive capacity? If we’re losing our sight or hearing, or if we wish we had the olfactory prowess of a sniffer dog, will we soon be able to purchase new senses to integrate within our existing nervous system? And what are the ethical and social issues around these questions? If we start to form a global human/technological interconnected cognitive cloud, who will own not just the data but the intellectual property? How could we ensure individual privacy, let alone autonomy?

In the meantime, the emerging field of neuromorphic computing, which entails designing computer chips that mimic the human brain’s neural structures and processing methods, is leading to more efficient handling of tasks such as pattern recognition and sensory data-processing. It might allow for substantial energy efficiency and improvements to computational power, and even serve as one of the building blocks of artificial super-intelligence.

## The hive mind and an evolutionary leap forward

When I try to survey the interconnecting mega-technologies that we humans have created over the last forty-odd years – from new communication platforms that enable billions of us to share our views, to neurotech tools that allow minds to be literally coupled together, to AI systems that can create new meanings about our world and then communicate them using LLMs – it’s hard not to marvel at the exquisite confluence of so much cognitive work.

As we saw at the beginning of this journey to understand the human brain in the twenty-first century, there’s accumulating evidence that humanity is undergoing a major evolutionary transition. We seem to be shifting towards collective intelligence and away from individuality, to creating a socially

integrated mega-group on which the effect of culture supersedes that of our individual genes. This is all being amplified by the technologies we seem compelled to create, which enable us to share perspectives and ideas more readily across our species. With AI coming on board, how will we continue to amplify our cognitive skills? Perhaps it's only by running the experiment that we will find out what the process of amplification looks like.

As Martin Picard, the expert on mitochondria and bioenergetics, told me: 'In my view, life is what happens when energy flows<sup>28</sup> through an almost infinitely complex biological system. The DNA or the proteins or any other component of that system is not the source of life, just part of the physical structure that the dynamic energetic process happens to need to come into being. A body and a brain are a kind of hardware, an infrastructure that helps to propagate the flow of energy we call life. Perhaps AI displays analogous emerging properties. It's not a thing, much less a thing that's alive, but maybe it too is a process.'

When I was a young teenager, one of my favourite books<sup>29</sup> was Neal Stephenson's *The Diamond Age*, a science-fiction thriller about a dystopian world where a digital 'Smartpaper' fed you with personalized news, people went to the 'mod parlour' to get cybernetic implants and children were educated by an AI tool called 'the Primer'. Another favourite was<sup>30</sup> Geoff Ryman's *The Child Garden*, set in a future transformed by climate change, in which people, modified to photosynthesize energy, stretched out in the morning sun to fuel themselves for the rest of the day. Thirty years later, we may not have inserted plant genes into ourselves, but we are having scientifically informed discussions about how to optimize our own energy production. AI is increasingly being used in schools, the propagation of news and entertainment via social media has become part of everyday life, while people are increasingly hacking their nervous system with implants. These ideas no longer live solely in the imagined worlds of science fiction, cyberpunk and the musings of a teenager. What else can we imagine? Where else can our extraordinary human intelligence take us?

# Epilogue

SOMETIMES I THINK OUR POST-INDUSTRIAL, individualistic, consumerist, highly driven and ‘always on’ society resembles nothing so much as a group of army ants stuck in a perilous pheromone trap. Unless you’ve seen this situation, the analogy won’t make intuitive sense. The poor ants get themselves locked<sup>1</sup> in a dysfunctional loop, following each other’s pheromones in a never-ending circle. They’re so motivated to keep blindly going that when this error occurs, they trudge endlessly round and round in a death spiral until they expire from exhaustion. They will even move dead ants out of their way to keep going and maintain the status quo of their behaviour. It’s a peculiar phenomenon, an example of collective intelligence gone hideously awry.

Are humans currently in an equivalent of the death spiral? If so, maybe AI can help open our eyes to our energy waste and negative feedback loop, to help us break free from our blinkered consumerist treadmill? Maybe technology will be the illuminating factor that helps us to break away and use our cognitive resources more effectively? Is it too much to hope that the coming together of the game-changing new technologies we seem to be compelled to develop at the moment, and the almost existential level of threat that life on Earth is facing, will act as the disruptive force that breaks the spell cast by consumerism and personal gratification, comfort and familiarity? Could technology not only free up our time and support our creative and intellectual endeavours but help us to understand what truly makes our species intelligent? I hope that it will act as a reminder that our collective gifts are wondrous, and spur us to work together, with determination and imagination, to face the issues that are threatening the survival of future generations. This crisis could be the making of us if it forces us to set aside the self-destructive hubris that has driven us to behave as if we are separate from nature rather than part of it. We urgently need to

nurture and deploy our staggering skills in the service of our children and our society so that as many people – and other non-human beings – as possible can flourish into the next century.

As we've seen, humans are particularly creative, innovative and insightful in liminal states: think of that moment between sleep and waking when our mind serves up great ideas, intriguing thoughts, startling images and, sometimes, the perfect solution to a problem. On a longer timescale, adolescence is a richly creative, energetic and exploratory phase between childhood and adulthood when our whole neural architecture is transitioning between one state and another. But even sitting on a train or a plane between two destinations, or being on holiday between two chunks of everyday routine, can create opportunities for mind-wandering and reflection. Novel situations and uncertain times have always been an invitation to humanity to rise to the challenge. When we explore new places and meet different people, we expand our perspectives. Our neural circuitry literally creates new maps in our minds so that we can navigate by way of new thoughts. This may take effort but it's the work we've evolved to do.

While I would argue that we've made mistakes and poor choices throughout our history (repeated genocides, the slave trade and weapons of mass destruction spring to mind), I don't believe we need be despondent about where we are, so long as we can summon the determination and bravery to live more intelligently and make better decisions. In their book *Existential Hope*, futurist and philosopher SJ Beard wrote: 'As Carl Sagan noted, we are a young species<sup>2</sup>. Homo sapiens evolved perhaps 300,000 years ago, and the average mammalian species can expect to last ten times as long. Yet we have been living with industrial technologies, secular philosophies, massive populations and globe-spanning institutions for only around 300 years; 0.1 per cent of our history. It is no wonder that we feel lost and confused and struggle not to harm ourselves with these new and powerful playthings. We still have a lot of growing up to do, a lot of learning about ourselves and our environment, understanding our capabilities and weaknesses and establishing sensible boundaries and making wise choices.'

Besides, we've also achieved great things, from the invention of agriculture to the wonders of the ancient world, the printing press to penicillin and even the humble paperclip. Humans are brilliant inventors, resourceful strategists, compassionate friends and supreme altruists. Now

we need to be brave as well as clever, and here too I wonder whether our newly invented tech might come to our aid.

In April 2025, I set off with my Australian friend Saskia on a hike through a Queensland national park along a remote 102-kilometre trail called the Cooloola Great Walk. The iconic route links Noosa North Shore and Rainbow Beach via a constantly changing landscape, from giant sand dunes, heath plains and everglades to rainforest, coastal woodland and a lake perched high up in the hills. Apart from Saskia and me, the only other person doing the trail from Noosa to Rainbow at the same time was a seventeen-year-old called Oscar, on an elective solo trek from his Steiner school. We bonded at the nightly camp spots – compared blisters and played card games. Saskia and I carried provisions, water, an emergency first-aid kit and our mobile phones, which had been equipped with an electronic tagging device that recorded our live location and transmitted it to her family. I offered to contact Oscar's family with regular location updates if it might help reassure them.

The Queensland landscape is astoundingly beautiful, but it can be deadly. It's full of some of the most venomous fauna in the world. Over the course of the trek, I had a very close encounter with a death adder (you can guess why it's so called), a baby brown snake (not sweet, exceptionally poisonous), pulled a blood-sucking leech from between my toes and removed a behaviour-altering tick from my belly button. Being a visiting Brit, I was immunized against fear by a certain level of ignorance, but Saskia and her family were not. They insisted we take our phones and a power pack and keep the live-tracking on.

I'm not sure that if I had been bitten by that adder, even the combination of emergency medical kit and mobile phone to call for help would have been enough to save me, but having both forms of back-up enabled Saskia and me to feel safe enough to be brave. Consequently we had an incredible and fulfilling experience that taught us a great deal, bonded us close and will stay in my memory for the rest of my life.

On our safe return to the welcome amenities of an Australian home, with its constant power, Wifi, well-stocked fridge and vibrating anti-snake devices on every outer wall, I got to reflecting on how crucial our phones had been to our adventure. We didn't need to use them, but knowing they were there meant we were bolder than we would have been without them. Perhaps this is another facet of the way our relationship with technology

can support us to live intelligently. We all need to feel safe to be able to strike out and explore. When we're fearful we cannot be smart, as we saw all the way back at the beginning of the book. If we're going to grapple with challenges as we must, think hard about our problems and reap the joy of living the richest life we possibly can, we need to feel safe enough to be curious and bold. We're often told that our smartphones and AI are threats to our intelligence and well-being, but when Saskia and I were hiking the Cooloola Great Walk, I felt grateful for them.

The stakes are high as we square off to the coming decade but, then again, the stakes have always been high for every human being throughout time. Luckily for me, and for you, we've got a brilliant package of cognitive superpowers we can call on. We just need to use them, for if we do, they will always have our back.

# Notes

## PROLOGUE

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## 1. EMOTIONAL INTELLIGENCE, EMPATHY AND COLLABORATION

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## 2. IMAGINATION, CREATIVITY AND FLEXIBILITY

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#### 4. ADAPTING TO UNCERTAINTY

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## 5. THINKING WITH CLARITY AND PRECISION

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## 7. GLOBAL CITIZENSHIP AND AI: OUR HEALTHY LONG-TERM PARTNERSHIP

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