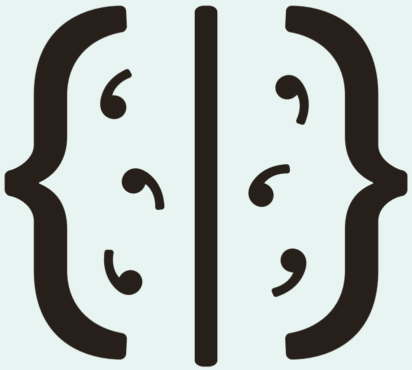
DK

the body literacy library

brain



an owner's guide

Elizabeth R. Ricker

the body literacy library

Body literacy is a human right. It is a means to observe, learn, and understand ourselves – three essential steps to enhancing our self-knowledge and self-care.

With *The Body Literacy Library* you will learn to tune in to every little bit of yourself, have all your embarrassing questions answered, and discover everything you need to know about your body to live a healthier, happier life. This isn't just about listening to your body, but empowering yourself with the knowledge of what your body is telling you.

Read this book to love the skin you're in, and make informed, positive changes to improve your health and wellbeing. Starting today.

Contents

Introduction 08

01 What's inside your head? 10

02 Brains at all ages 40

03 How healthy is your brain? 58

04 Healthy brain habits 68

05 Improving brain performance 94

06 What's bothering you? 110

07 Challenges and differences: psychological 124

08 Challenges and differences: neurological 146

09 Make it better, please! 160

Epilogue 184
Sources 186
Index 196

Acknowledgments 202

Introduction

Your brain is a glorious, mysterious marvel – but what if you could unlock a bit of that mystery? In the pages ahead, you'll plumb the electric depths of neuron's firing, discover what's different about left-handed people's brains, and uncover a possible link between hormones and fighting Alzheimer's disease – decades before the disease shows up.

Don't feel that you need to read the book in order. Let your curiosity lead you to whatever section piques your interest.

No organ is more personal than your brain. Despite a shared outer world, we all think, act, and feel surprisingly differently. Why? Because our brains have created different inner worlds. In fact, our lived experiences create patterns of neural connections that are more unique than our fingerprints. This book guides you towards your brain's healthy, unique potential.

Consider a moment when you were your most vibrant, your sharpest, your most generous, best self. How did it happen - and how might you unlock more moments like it? If you were ever puzzled at why you made a certain choice or wonder how happy you really are, you can thank (or blame) your brain. No other organ so profoundly affects how you work, study, play, or relate to others. It is the command center of your consciousness. Let this book be your guide to unlocking it.

We are living through a revolution in neuroscience and brain health. Just in time, because we are also experiencing a global mental and brain health crisis. Nearly 1 billion people suffered from a mental disorder in 2019. In 2022, the World Health Organization issued a position paper on optimizing brain health. Thankfully, virtual reality is now helping treat phobias and anxieties. Genome sequencing has detected disease-causing genes for many disorders. Telepsychiatry is providing far broader access to therapy, including previously under-served groups. Smartphones and wearables are being used to track patterns and triggers such as sleep, mood, and movement for mental health. They offer mindfulness apps and reminders, too.

It seems like every day I read about something related to brains in the news. The media is covering the wave of young people struggling with loneliness. Or people are worrying about whether we have all developed ADHD collectively – as distracting and pervasive as our phones and social media have become.

Outside the news, people keep telling me about the fear and uncertainty they feel when a friend or family member is diagnosed with a brain-health issue – everything from learning differences to tremors. Many are just puzzled by their own brain's productivity ups and downs.

So much in life is outside our control. Yet, better brain health makes everything else easier. Inside this book, you'll find more than just the essentials to better understanding your brain. You'll find quick, evidence-based practices you can start today. Additional tools and hacks can be found at my website (ericker.com). I'll be delighted to hear what your brain finds most interesting as it learns about… itself.

Let me know!

Elizabeth R. Ricker

01

What's inside your head?

how do we know what we know about the brain?

From what keeps you breathing to what keeps life worth living, neuroscientists claim that your brain is composed of the matter that makes you matter. But how do they really know that?

For millennia, philosophers have speculated about what produces our thoughts, emotions, personality, and behaviours. In the last 50 years, theories have been transformed into genuine understanding through brain imaging, genetics, and other scientific breakthroughs.

Learning from dead and living brains

Before brain scanners, neuroscientists studied the brain structure of animals that had died. Microscopes made these examinations more fruitful. Scientists could see individual cells and structures in the brain tissue, but they couldn't answer questions about living brains.

Computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) are imaging technologies that scan living brains. They provide information about the size, shape, and sometimes the functioning of brain parts.

In the 1920s, scientists developed the first brain imaging that could look at live brains in real time. Named electroencephalography (EEG), it enables a look at how the brain's electrical activity changes in response to situations in the world. After that, additional live brain scans emerged. Magnetoencephalography (MEG) was developed in the 1970s. It uses magnetic fields created by the brain's electrical activity to provide greater detail than EEG, but is more expensive.

Single-photon emission computerized tomography (SPECT), functional magnetic resonance imaging (fMRI), and functional near infrared spectroscopy (fNIRS) all measure changes in blood flow to areas of the brain. They identify which brain parts are active in any given task.

People, animals, and simulations

Accidents, disease, and other misfortunes can act as "natural experiments". One example was railway worker Phineas Gage, who survived a pole piercing the front of his brain, but his personality and impulse control changed. Scientists then realized that the front of his brain must have been responsible for personality and decision-making.

The way that our brains process the sensory world, how we learn, and other processes are often shared by animals. So, scientists study animals' abilities at these tasks to understand how humans do them.

"Neuropsychological assessments" are specially designed games used by cognitive

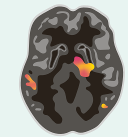
TYPES OF BRAIN IMAGING

measures structure

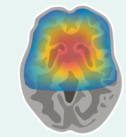
CT
shows cross-sectional images of the physical structure using X-rays

MRI
shows physical structure using large magnets and radio waves

measures blood flow

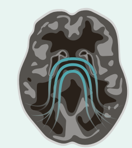


fMRI
shows blood flow using MRI plus additional computation to detect indirect measure of blood flow

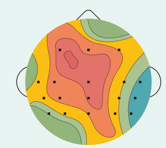


fNIRS
shows blood flow using near infrared light

measures electrical activity

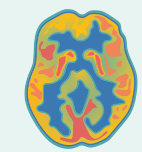


MEG
shows electrical activity using special detectors that identify tiny magnetic fields

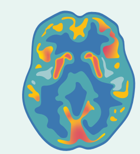


EEG
shows electrical activity using electrodes on the scalp

requires radioactive injection



SPECT
shows both blood flow and structure using 3D scans



PET
shows blood flow and metabolic activity by creating 3D scans

scientists to offer insights into mental processes such as memory, attention, and language. Scientists also use mathematical models to build computer simulations of specific brain functions and behaviour to help us make predictions about how real brains would behave.

Other technologies

Genes can direct the designs for both the structure of brains and how they function. Brain mapping, or connectomics, involves studying the wiring across different parts of the brain. Genetics and brain mapping promise to unlock the secrets of the root causes of disease.

Another key tool is neuropharmacology, which enables us to alter the ratios of key neurotransmitters in the brain in cases of imbalance. Brain computer interfaces (BCIs) connect a human brain to a computer so that they can communicate or move artificial limbs. Through stem cell research, we may gain the ability to grow new brain cells to replace old or damaged ones, while gene editing may prevent disease by never allowing cells to produce problematic designs in the first place.

the structure of the brain

The complex structure of the human brain has evolved to reflect its functional role in the body. Let's look at where certain functions show up in the brain.

Animals such as squids, chimpanzees, crows, and elephants can problem-solve and use tools, but what makes humans different may be our larger, more recently evolved neocortex. This region is home to the brain networks that are most active during cognitive tasks.

The cerebrum is defined by sulci and gyri – grooves and ridges. They reflect nature's best attempt to fit a big brain in a small box – that is, your big neocortex stuffed into your small skull – to expand the surface area available.

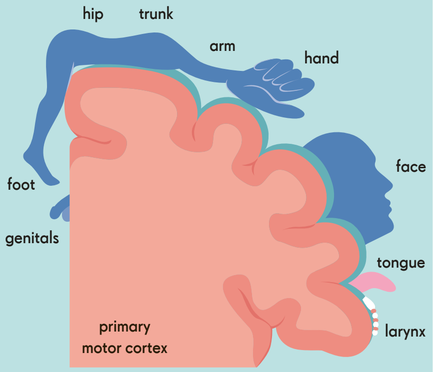
Other regions are more similar to the brains of other animals. One is the hindbrain, an ancient structure that helps manage basic life functions such as breathing, heartbeat, and digestion. We also share a lot of similarities with other animals in terms of the structure and function of our midbrain. The midbrain manages a variety of tasks, including our movement and aspects of vision, and it regulates our sleep and wakefulness.

Layers of protection

The brain and spinal cord are bathed in cerebrospinal fluid (CSF) with a series of plasma pools called ventricles. The CSF serves as a protective plasma that acts as a cushion, provides buoyancy, and enables an optimal chemical environment for brain cells' electrical and chemical transmission. The blood-brain barrier acts as a special filter enabling the brain to access blood nutrients such as glucose, amino acids, and oxygen, but protecting it from many of the pathogens that might be present in the rest of the body's blood.

THE "LITTLE PERSON"

Each of our body's sensations and movements is managed by a different area in the homunculus. Here the different sizes of the body regions reflect how much brain power is devoted to each one.

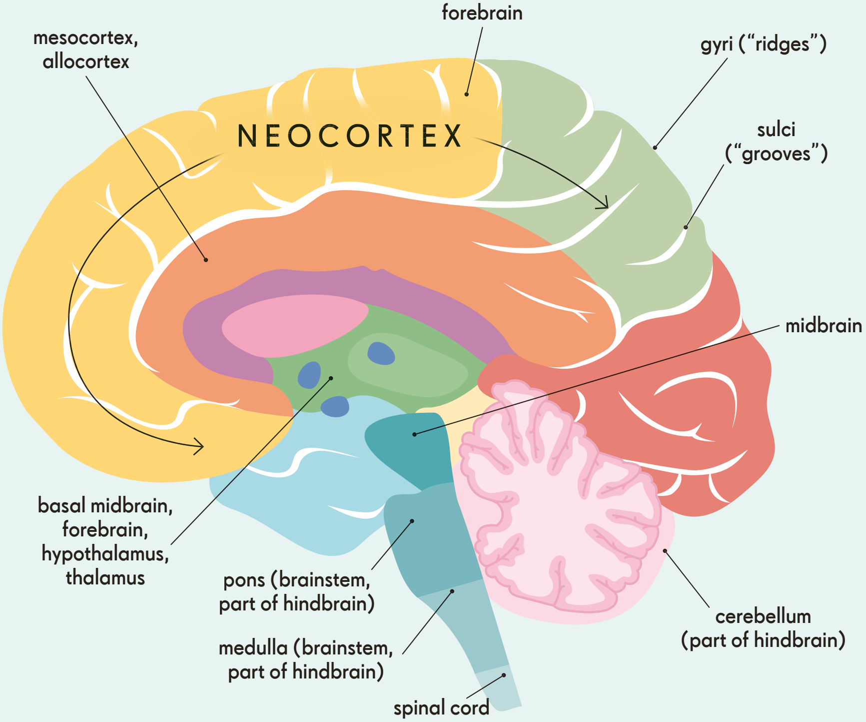


The homunculus

There is a region in the top, front part of your brain, in the cerebral cortex, that reflects specific parts of your body, and it's called the homunculus, which means "little person". For each part of your body, there is a region on the homunculus that manages its sensations and movements. Your hands, mouth, and face are all very sensitive, so there is more cortex devoted to each of these areas. Your back, which is less sensitive, has less cortex devoted to it. This is an example of how the brain uses the importance or complexity of a bodily function to decide how much real estate to devote to it.

REGIONS OF THE BRAIN

Some brain regions (e.g. the neocortex) enable conscious thoughts. Others (e.g. the hindbrain) enable automatic tasks like breathing and circulation. All work together to create your experience of the world.



neuroplasticity

Neuroplasticity is the brain's way of physically and functionally changing to adapt to experiences – especially challenging ones.

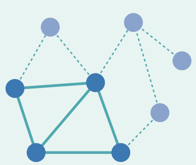
Across studies, we see the brain undergo structural and functional change in response to adversity, which enables us to deal with challenges. These changes include new neurons growing, as well as old neurons expanding or modifying, and are known as neuroplasticity. We see the systematic strengthening or weakening of the synapses that connect the neurons. There is the brain rewiring itself into new patterns. Then, there are whole areas of brain tissue growing or shrinking in size. Neuroplasticity can also encompass systematic changes to activity in hormones and neurotransmitters. All of these changes typically occur in response to a significant experience. Often, it's in response to a challenge of some sort.

We know about neuroplasticity from brain imaging evidence from healthy people adapting to learning challenges. Another source of understanding is from clinical observations of patients recovering from injuries. In addition, there is cellular and molecular evidence of brain changes in other animals.

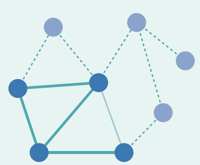
Neuroplasticity can be evaluated in a number of different ways, from detecting molecular and protein changes to measuring neuron activity, some of which are illustrated on the next page.

CHANGING SYNAPSES AND NEURONS IN NEUROPLASTICITY

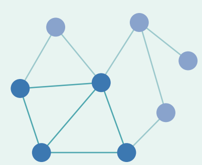
Psychologist Donald Hebb coined the concept of associative learning, where "neurons that fire together, wire together". Connections are further strengthened through repetition and weakened through disuse.



strengthened synapses
these can come from changes in the chemicals released in or near the synapse or from changes in structures of neurons around the synapse



weakened synapses
reduced neurotransmitter release and receptor sensitivity; uncoordinated firing between neurons



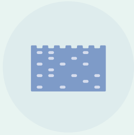
new synapses
increased neurotransmitters released; coordinated firing between neurons; increased neurotrophic factors

DIFFERENT EXPERIMENTAL MEASUREMENTS OF NEUROPLASTICITY

neurogenesis
the formation of new neurons, initially in the embryo, but also later in life

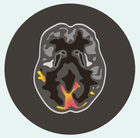
long-term potentiation (LTP)
particular patterns of electrical activity can stimulate increases in neurotransmitters and proteins that create more neural signals

axonal and dendritic length
altering the length of neuron ends



synaptic proteins
BDNF (brain-derived neurotropic factors) and others that affect synapse formation or closure

dendritic arborization, morphology, and length
altering the branching pattern of a neuron's signal receivers (dendrites), the structure and the length of them influences how they communicate



brain activity
experience can alter which networks of neurons are stimulated and active

Challenges that can trigger neuroplasticity

Consider recovery from a stroke. Undamaged, nearby brain areas may compensate for the damage. This "rewiring" might involve new connections, electrical shifts, or even changes in neuron size or structure. Though damaged tissue may not fully recover, the brain adapts to regain function.

Ever felt like your brain was stretching in school? It turns out that students cramming for high-stakes tests show measurable changes in multiple brain regions including the hippocampus and frontal cortex. Scientists have observed neuroplasticity in students revising for undergraduate, law, and medical school exams.

Other examples of neuroplasticity at work include learning to juggle or play a musical instrument. For aspiring London taxi drivers, learning the city's street layout is tested in an exam called The Knowledge. The size of a trainee black cab driver's hippocampus changes during this challenge. Those who did better in the exam experienced more brain modification than those who did worse. Finally, patients undergoing intense psychotherapy show brain changes, too.

Neuroplasticity in our everyday lives

Regular learning and memory may occur under less dramatic circumstances. Yet, neuroplastic brain change is often hard won. We often see it under circumstances of trauma, injury, or intense training that occurs for hours a day and weeks on end. If you want dramatic brain change – the kind where your brain reorganizes itself, rewires itself, or remaps itself significantly – it will take effort.

electricity in the brain

Our brains are electrical – even at rest, they generate the electricity of a 20-watt electric light bulb. Individual brain cells generate hundreds of electrical impulses each second.

Electrical signals are the brain's fast-acting communication system. Electricity sizzles along the outside of a neuron, building to a crescendo. If that wave of electricity is strong enough, one neuron will send a message to the next one.

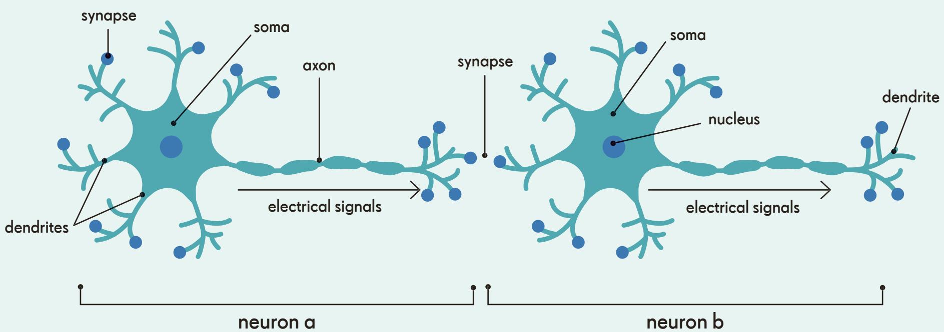
Electrical signals at work

Sodium-potassium pumps lie along the outside of the neuron. These regulate whether electrical signals move from neuron to neuron. Those signals are called action potentials. Before the electrical signal arrives, the sodium-potassium pumps maintain an electrical-chemical imbalance across the neuron's membrane. They do this by allowing fewer sodium ions to come in than potassium ions.

If enough electricity builds up, though – and it hits a certain threshold – the pump allows sodium ions in. That lets even more sodium ions come in, driving the pump to open even more. This feedback loop drives the electrical wave to travel down the neuron's axon. Eventually, it reaches the end of the neuron, which contains

NEURONS AND SYNAPSES

Electrical signals travel from neuron A's soma (cell body) down its axon through to its dendrites (branches). The dendrites of neuron A interface with the synaptic terminals of neuron B, which generates an electrical signal that passes down neuron B's axon through to its dendrites.



a gap – the synapse – with another neuron on the other side. If the action potential is strong enough, it will trigger chemicals to be released across the synapse. If enough neurotransmitters get released, a new electrical signal is generated, which will also travel to the next neuron. In the case of a gap junction – a special type of channel – the same electrical signal quickly jumps from one neuron to the next.

The dendrite, a finger-like appendage, is where the next neuron will receive the previous neuron's message. The neurotransmitters that get released by one neuron into the synapse either empower the next neuron to fire or stop it from firing.

Specific signals

The story doesn't end with one neuron talking to one other neuron, of course. Your brain is a biological universe composed of billions of neurons all talking to each other. Across the entire brain there are networks of neurons that work together on specific functions. Memories, for instance, get stored in the brain by having neurons fire in a particular pattern. This firing strengthens the connections between them, making them more likely to fire in the future, too (see pages 16–17).

There are patterns of electrical activity across the brain where neurons fire in rhythmic frequencies. These are called brain waves. Depending on the frequencies, these brain waves tend to correspond to certain mental or emotional states. Examples include beta waves common in focused states and theta waves in daydreamy, slow states.

• CAN WE REALLY MOVE THINGS WITH OUR MINDS? •

Something called "brain computer interfaces" (BCI) enables exactly that. BCIs work by reading patterns of electricity, magnetism, or blood flow from your brain using EEG, fNIRS, or other technologies (see brain imaging on pages 12–13). Then, those brain signals get sent to a computer. The computer interprets the signals it receives. It could move a cursor on a screen or a robot arm – all based on your thoughts. Imagined movement activates the same brain areas as real movement. For paraplegic patients who cannot move their own hands, brain computer interfaces – combined with their own brain's imagining of movement – may be enough to move a robot hand instead!

chemistry in the brain

More than 20 per cent of the chemical energy produced in our bodies is used by our brains. Some chemicals are released every few seconds, while others take over a decade after birth to be released in larger quantities.

Electrical synapses are faster than chemical synapses, but too many electrical synapses in a row can lead to a degraded signal within the brain. So, for longer-range signals, chemical synapses dominate.

The chemicals at work

Five neurotransmitters play key roles in synaptic signalling in the brain. When released into the synapse and received by nearby neurons, they can trigger or halt the firing of neurons. The mnemonic I use to remember these five is "saggy dog" – SAGDG stands for serotonin, acetylcholine, GABA, dopamine, and glutamate. Increased serotonin release tends to be associated with feelings of well-being and satisfaction. More acetylcholine tends to be released when levels of alertness are high and/or when learning something new. GABA is inhibitory, and it tends to be the antidote to anxiety and stress, released when your body is calming down.

Dopamine is all about goal-orientation, motivation, and anticipation; it is released when a reward is expected. Glutamate tends to increase alertness or stress. It is helpful when learning or focusing, but too much can be associated with anxiety. Two other chemicals act simultaneously as neurotransmitters and as hormones: norepinephrine and epinephrine.

A myriad of other chemicals exist in the brain, too. For instance, there are channel proteins that determine when an action potential (see pages 18–19) happens in a neuron. There are hormones for many jobs. To promote sleep, for example, there's the hormone melatonin. In managing the stress response, you'll discover multiple hormones in the mind-body connection section (see pages 20–25). Special molecules called cytokines participate in repairing neurons after injury, infection, or neurodegeneration, though in high numbers cytokines can cause harm.

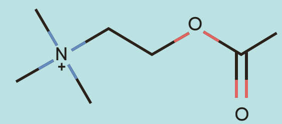
There are many chemicals in the metabolic pathways serving the brain's massive need for glucose, too.

The role of genes

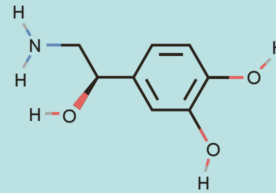
Finally, we consider genes and the area of epigenetics. Genes are made up of DNA, the initial blueprint of cells. Genes affect expression of neurotransmitters and other brain chemicals. Epigenetics respond to environmental factors. They act as a kind of editing system on DNA to help decide which genes get expressed and which don't. All of these chemicals work together to decide how your brain will function.

CHEMICAL STRUCTURES OF NEUROTRANSMITTERS

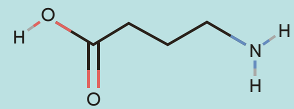
These are the main neurotransmitters in the human brain, each one having a different effect on the central nervous system.



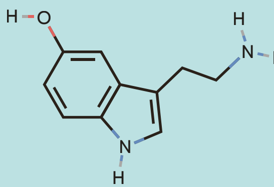
acetylcholine
memory and muscle activation



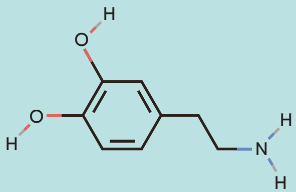
noradrenaline
alertness



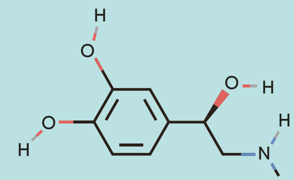
GABA
inhibits neuronal activity



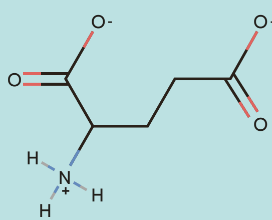
serotonin
regulates mood and emotions



dopamine
manages reward and motivation



adrenaline
fight-or-flight



glutamate
excites neuronal activity

emotions, motivation, and reward

Brain pathways ranging from the most recently evolved to far more ancient systems determine your emotions, motivations, and what you find rewarding. Let's explore a few of the key structures and their functions.

Specific brain pathways are involved with your emotions, motivation, and reward. The limbic system processes emotions and memories associated with reward, such as our first love. The mesolimbic pathway is triggered by enjoyable experiences – tasty food or good conversation – and makes us want to repeat those experiences. It connects the ventral tegmental area (VTA) to the nucleus accumbens in the forebrain.

The mesocortical pathway connects the VTA to the prefrontal cortex. It helps with planning and focus – an example is breaking down a big assignment and working steadily up to the deadline. The nigrostriatal pathway controls movement and helps us learn physical skills, such as dancing.

The limbic system

The limbic system plays a huge role in your emotional operating system. Nestled in the middle of the brain, it includes a variety of sub-regions including the amygdala, hippocampus, and hypothalamus. Your amygdala – meaning "almond" in Latin – is named for its shape. It helps you process salient or highly charged emotional events, as well as form memories about them.

The hippocampus (Latin for "seahorse", and also named for its shape) is right next door. It handles your memory more broadly, but it includes emotional memories, too. In addition to emotion, your hypothalamus manages primal urges such as your thirst, hunger, and sexual drives.

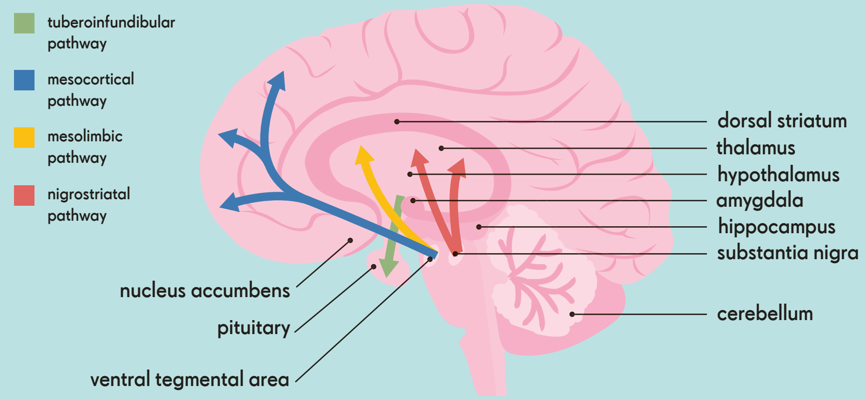
Outside of the limbic system, your insula facilitates your bodily and emotional self-awareness. Latin for "island", this part of the brain facilitates the mind-body connection. When you feel an emotion or sensation in a particular part of your body – say, butterflies in your stomach when nervous or excited – you can thank your insula. For more on your mind-body connection and stress, see pages 24–25.

• DOPAMINE AND OPIOID ADDICTION •

In 2019 alone, the World Health Organization (WHO) reported nearly 500,000 deaths worldwide related to opioid use. The brain adapts to the high dopamine release from opioids by lowering its natural production. When users try to quit, their dopamine levels plummet, triggering intense cravings. Recent research suggests that dopamine's role may be more nuanced. Not only is it involved in reward, but it may be involved in the motivation to escape negative situations. Finally, dopamine plays a role in the sense of relief when overcoming adversity – such as overcoming addiction.

DOPAMINE PATHWAYS

The tuberoinfundibular pathway helps you feel calm or sleepy, but dopamine plays a bigger role in the mesolimbic and mesocortical pathways that are also more involved with emotions, motivation, and reward. The nigrostriatal is influenced by dopamine, but in physical activity more than feelings.



Motivation and reward

Two other regions in the midbrain, the nucleus accumbens and ventral tegmental area (VTA), dictate your motivations. The nucleus accumbens plays a role in your motivation and how you register a reward; it also helps reinforce pleasurable activities. The VTA is the factory for dopamine, the key neurotransmitter that manages motivation. Dopamine makes us want to repeat whatever actions triggered the release of dopamine in the first place, and is released along a series of finger-like paths called the mesolimbic pathway. This is also understood to be involved in drug and alcohol addiction.

the mind-body connection: stress

Ready to meet the systems that form your mind-body connection to stress? Each acts on a different time scale, from milliseconds to minutes, and they regulate each other in a feedback loop.

The system that revs you up during a stressful event is called the sympathetic nervous system (SNS). Within the SNS, there are two subsystems. One is fast-acting, the other is slow-acting – the hypothalamic-pituitary axis (HPA). The system that calms you down after the event is over is the parasympathetic nervous system (PSNS).

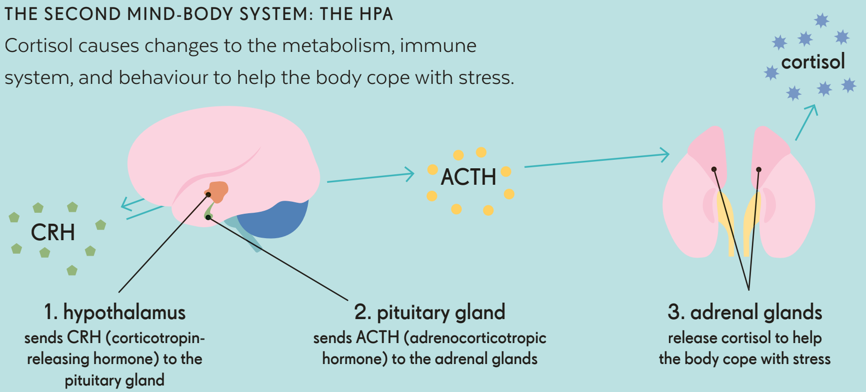
When you get stressed

Imagine you're about to give a speech but you fear public speaking. Your palms get sweaty, your throat clenches, your mind goes blank. Why? You can thank the first of the systems: the SNS.

Often referred to as "fight-or-flight", the SNS helps us survive life-or-death situations. Within milliseconds, it increases your heart rate and dilates your blood vessels so you can run or fight. It redirects blood flow away from your internal organs and back to your muscles. A neurotransmitter called norepinephrine carries the "fight-or-flight" message. It races along nerve fibres extending from the middle and lower regions of the spinal cord.

THE SECOND MIND-BODY SYSTEM: THE HPA

Cortisol causes changes to the metabolism, immune system, and behaviour to help the body cope with stress.



You just experienced the first subsystem of your SNS. You had a rush of adrenaline, thanks to your hypothalamus prompting your adrenal glands, just over your kidneys. There's also a slower SNS subsystem – the HPA. It kicks in a few minutes after you start your speech. Signals travel from your hypothalamus to your pituitary, a gland near to the hypothalamus. Then, your adrenal glands release cortisol, another stress hormone.

Time to calm down

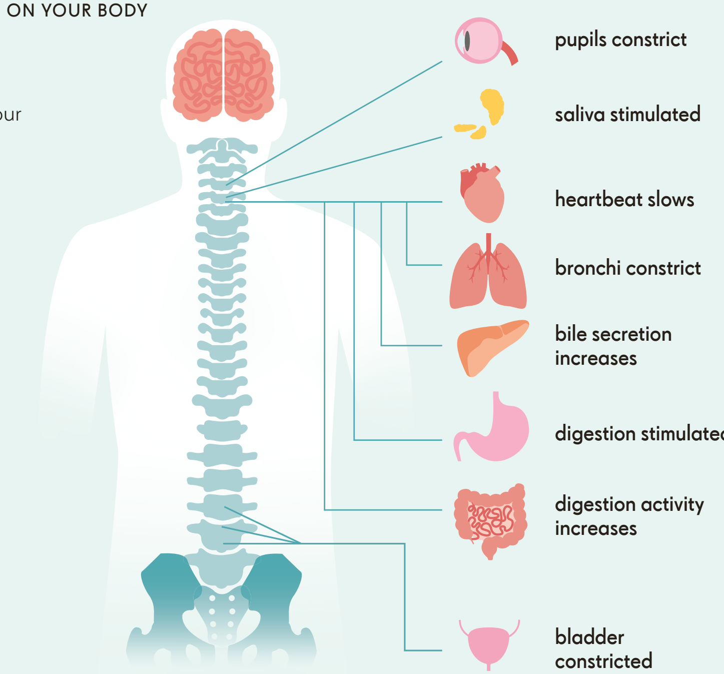
The final mind-body system regulating stress is the PSNS. Sometimes termed the "rest-and-digest" response, it re-establishes calm after the "fight-or-flight" response ends. If you finished your speech and it went well, your body switches to a new goal: conserving energy. Time to slow down your heart rate and re-promote digestion – during the sympathetic response, your blood was going to your muscles instead of your digestive organs.

It's also time to turn back on your immune system. The neurotransmitter acetylcholine helps carry out these tasks. It is carried by nerve fibres emanating from parts of the spine on the back of your neck and your upper buttocks.

So, stress isn't all in your head. In fact, it takes over many parts of your body!

HOW THE PSNS ACTS ON YOUR BODY

Once danger has passed, nerve fibres carry messages to your brain telling it that it is safe to restore the metabolism and immune system. The illustrated changes occur in the body.



biological rhythms

A better understanding of your biological rhythms can help you optimize when to schedule hard mental tasks, creative projects, or physically demanding projects.

Our biological rhythms can help us plan our days in a neurobiologically smarter way. You may have heard of circadian or diurnal rhythms. Circadian rhythms are 24-hour biological cycles that are generated internally, while diurnal rhythms are set by external factors – such as day and night cycles set by exposure to light.

Our sleep-wake cycles are roughly 24 to 25 hours long. They are regulated by the suprachiasmatic nucleus (SCN), which is the "master clock" in the brain's hypothalamus that gets reset by daylight. The SCN regulates the behaviour of the hormones melatonin, cortisol, and insulin. These determine your peak alertness hours, when you fall asleep, and when you feel hungry. Exactly when those peaks occur depends on your chronotype.

• TYPES OF BODILY CYCLES •

Ultradian cycles are shorter than 24 hours. These include sleep, heart rate, and breathing cycles. These are all regulated by multiple parts of the brain. Gaining control over breathing and heart rate are the active ingredients in certain types of therapy (see pages 86–87).

Infradian cycles are much longer, including the menstrual cycle and pregnancy. Each of these cycles involves brain regions such as the hypothalamus and pituitary gland. Tracking the peaks of energy, mood, and alertness levels that come with these longer cycles can help you understand what is normal for you. Then, you can tailor your activities to match these rhythms to improve wellbeing and productivity.

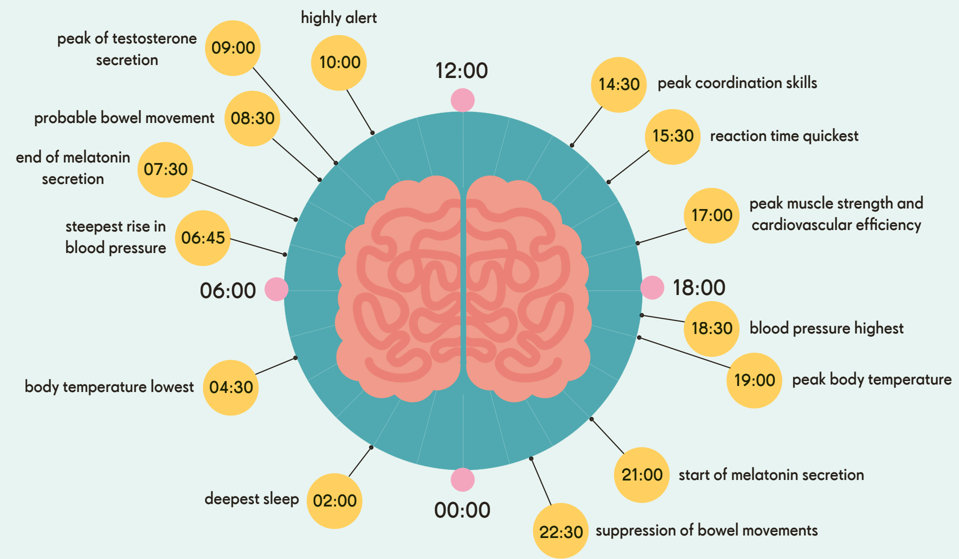
Morning larks and night owls

Your chronotype plays a role in answering this. A chronotype is the preference for being active during certain times of day. There are hundreds of genes that contribute to a person's chronotype and internal clock.

For "morning larks", the first few hours after waking is the best time for detailed mental work. For "night owls", the best bet for focused problem solving is to wait until alertness levels rise in the afternoon. For creative work, decreased cognitive inhibition works better than focused attention. So, morning types should schedule creative work for later in the day; vice versa for evening types.

For peak physical performance, the role of evening versus morning types is less clear. One finding dominates, though: for activities requiring power – such as weightlifting or sprinting – late afternoon or early evening works best. The internal body temperature is higher, muscles are looser, and chemical responses are quick. For what to do when you fall out of sync with your body's cycles, see pages 74–75.

PEAK TIMES FOR BODILY ACTIVITIES ACCORDING TO CIRCADIAN RHYTHMS



senses and perception

Your five senses gather information from your environment, which the brain processes and then interprets to give you a complete view of the world.

Senses work through a combination of sensory organs in your body, electrical signals, and processing regions in the brain. In sight, for instance, you have special rod and cone cells in your eyes that respond when light hits them. Then, they generate electrical signals to send to your brain. The key part of your brain that takes in electrical signals from all of your senses is called the thalamus. It is like a relay station in the middle of your brain.

To get processed further, the thalamus sends new signals back out to different sensory-specific parts of your brain's cortex, such as the visual and auditory centres. Eventually, your brain makes sense of all these streams of information and builds a unified view of what's going on in the outside world.

Sight

The process of sight involves light and visual data initially entering your eye. After some of the signal is routed through the thalamus, electrical impulses pass to your visual cortex, in the back of your head. This is in the occipital lobe of your brain. This brain region processes light, colour, shape, and motion. Information about what objects are ("it's a bird!") ends up being processed in the ventral stream (the "what" stream). Information about where objects are located in space ("the bird is flying through the trees overhead!") gets processed by the dorsal stream (the "where" stream).

Sound

With hearing, sound initially enters your ear. After some of the signal is routed through the thalamus, electrical impulses pass to your auditory cortex, located on the side of your head. This is in the temporal lobe. This brain region processes frequency, amplitude, and other components of sound. To process language, signals travel to specific regions of the left hemisphere called Wernicke's and Broca's areas. For more on language, see pages 34–35.

Touch

Touch is part of your somatosensory system. This includes skin sensors that detect pressure, temperature, vibration, itching, pain, and injury. It also allows you to discriminate between different textures, quick brushes, and even the movement or placement of your body through space. After some of the signal is routed to the brain's thalamus, a region in the parietal lobe

called the somatosensory cortex takes over. Often, we generate movements based on touch. For instance, if something itches, we move to scratch. The frontal cortex contains the primary motor cortex, which controls muscle movement.

Taste and smell

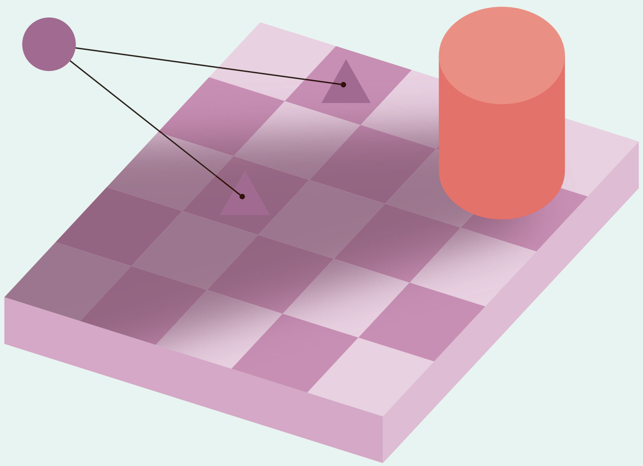
Smell through your nose and taste through your tongue are linked. After some of the signal is routed through the thalamus, taste is first processed through the gustatory cortex in your brain. This helps you distinguish sensations like sweet, salty, sour, bitter, as well as a "meaty" taste referred to as "umami" (what we taste in meats like steak). Both taste and smell are processed in a frontal brain region called the olfactory cortex, too.

Illusions in the brain

Any of your senses can be tricked. Due to its processing limitations, the brain uses shortcuts. One of these shortcuts is recording relative differences and changes, rather than absolute values. The chessboard image below shows this in the context of an optical illusion.

As an example of the same, here's a tactile illusion you can try at home. Immerse one hand in very cool water and the other in very warm water for one minute. Then, plunge both in the same lukewarm water. To the hand that was in very warm water, the lukewarm water will feel cool. The lukewarm water will feel very warm to the hand that just came out of cool water. Illusions reveal hidden limitations in our brain's ability to process sensory information.

CHESSBOARD OPTICAL ILLUSION
The two chessboard squares are the same colour, but the part-shadow created by the orange cylinder makes them appear very different. Here, our eyes tell us one story, but our brains revise it.



your brain health questionnaire

Before looking at how to maintain our brain health, take 10 minutes to evaluate the health of your brain right now.

Understanding your brain, and how well it is functioning, can be revealing. For the following 10 topics, indicate whether you agree with the statements below. Consider your brain's abilities on a typical day. Pick a timeframe for your reflection, such as over the last 30 days or 3 months, and record your answers.

The following assessment is for educational, not clinical purposes. Do not use this as a medical diagnostic. It assumes a baseline of solid health and simply helps you identify opportunities to optimize further. If you have any concerns, please consult your doctor.

For the following questions, answer:

1 infrequently
2 half the time
3 often
n/a I don't know or it doesn't apply

1. Cognition Matters relating to attention, learning, memory, decision-making, problem-solving, judgement	**a.** I can pay attention when I need to
	b. I can learn when I need to
	c. I can remember what I need to
	d. I can make decisions well (e.g., logically)
	e. I can solve problems well (e.g., quickly)
	f. I can make judgements well (e.g., socially)
	g. I can organize and plan as much as I need to

2. Autonomic foundations Staying alert during the day, falling and staying asleep, eating and drinking to satisfaction and without pain, having enough energy	**a.** I have the physical, mental, and emotional energy that I need
	b. I am alert when I need to be
	c. My sleep is good: I get the quantity and quality I need
	d. My sleep is good: I can both fall asleep and wake up when I need to
	e. My eating is good: after eating, I feel satisfied and able to attain fullness between meals; no distracting pain or other symptoms; I am able to recognize my hunger and satisfy it
	f. My hydration is good: I get the quantity and quality of water that my body needs, and I urinate a few times a day, and it is pale yellow
3. Social health & functioning Are you lonely? Are you satisfied by your relationships? What is your place in a larger network or community?	**a.** I am not lonely
	b. I am satisfied in my relationships
	c. I am satisfied with my community or network
	d. If I got sick or hurt, someone would notice or take care of me; if I needed help, I have someone I can reach out to

focus and productivity

We all feel vague and unfocused at times, but applying a few simple techniques can make a big difference to your concentration levels. Here are some short- and long-term strategies that are evidence-based.

Strategies for immediate improvements

01. Check your goals Sometimes we can't focus because it's just not clear what we should focus on. To make sure your goals are clear, turn them into SMART goals. The S stands for specific, M for measurable, A for achievable, R for relevant, and T for time-based. An example of a SMART work session goal would be: "I will complete this 250 word essay in the next 60 minutes. It's achievable because I did something similar yesterday. It's relevant because if I complete it, I'll be closer to completing the 10 mini-essays due by the end of the month."

02. Check your environment Is your environment too hot, cold, or loud? Are you emotionally upset or do you feel unsafe? Are you being constantly interrupted? Your brain will not be able to focus well under any of these circumstances (see pages 103 and 116).

03. Get a small dose of moderate exercise As little as 10 minutes of brisk walking can improve mood and energy as effectively as half cup of coffee.

04. Optimize your schedule for uninterrupted and intense mental work Because interruptions wreak havoc on the attention system, it is worth planning your work to avoid interruptions. For small projects, the Pomodoro technique (see below) is a useful approach, while for larger tasks or activities, time blocking offers a solution. This is where you set your own calendar events specifically devoted to solo work or activities.

05. Take intentional breaks Taking short breaks during prolonged work can recharge your ability to focus and can also prevent burnout and mental fatigue. Going outside in nature, connecting socially, or exercising are all evidence-based ways to recharge.

• THE POMODORO TECHNIQUE •

Take a task that can be completed in a short period of time, such as 25 minutes. No interruptions are allowed during this time, after which you have a short break. You earn a longer break after completing four consecutive 25-minute work stretches.

Strategies for longer-term improvements

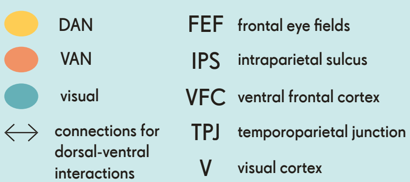
01. Social support (and healthy pressure) Ask a friend, family member, or mentor to be your accountability buddy. They can help you set meaningful, achievable goals and to hold you accountable for hitting them. This can be done with a short text once a day or a weekly check-in phone call where you share updates and receive feedback.

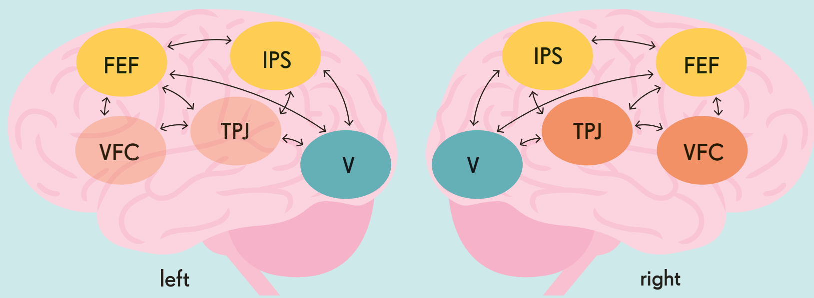
02. Mindfulness-based, biofeedback-based, or neurofeedback-based meditation From MRI and observational studies, we know that meditation and mindfulness-based practices strengthen the attentional circuitry in the brain. In as little as 10 minutes of meditation a day, you can improve your ability to sustain focus. For a more concentrated dose, you could try biofeedback or neurofeedback-based meditation (see pages 180–81).

03. Health and lifestyle check Sometimes, problems with focusing have their roots in trying to manage stress, insufficient sleep, or nutritional or hydration issues. If your lack of focus persists, check whether you may have any general medical or specific mental health issues.

HOW YOUR BRAIN WORKS TO KEEP YOU FOCUSED

Imagine searching for someone in a crowded room. Your dorsal attention network (DAN) guides goal-oriented search. Your ventral attention network (VAN) detects salient information. Both networks' interaction enables you to scan ("not her, not her") and adjust your focus ("wait, was that her perfume?"). This helps you find your target faster.





index

Page numbers in **bold** refer to main references, *italic* numbers refer to the illustrations

A
abuse 76–7
acceptance and commitment therapy (ACT) 173, 182
accipital lobe *34*
acetylcholine 20, *21*, 25, 119
action potentials 18, 20
addiction 22, 88, **128–9**, 179
ADHD (attention deficit hyperactivity disorder) 36, **130–31**, 132, 170, 179, 180
adolescence **44–5**, 72, 88–9
adrenal glands *24*, 25
adrenaline (epinephrine) 20, *21*, 25, 136
adverse childhood events (ACEs) 77
advocacy 162
aerobic exercise 82
ageing 50, **54–5**, 57
air pollution 76
alcohol 151
allocortex *15*
Alzheimer's disease 50–51, 75, 119, *148*, 149, 178
amphetamines 170
amygdala: and addiction *129*
  and anxiety 136
  and emotions 22
  and relaxation 86
  and stress 84, *85*
  and worry 117
  autism 134
  benefits of nature 91
  decision-making 102
  learning and memory 32, *33*, 100
  loneliness and 80–81
  mental loops 123
  post-traumatic stress disorders 144
  reproductive brain 46, 47
anchoring bias 103
andropause **52–3**
aneurysm clipping 169
animals 12, 14
anterior cingulate cortex (ACC) 102
anticonvulsants 170
antidepressants 170
antioxidants 78
antipsychotics 170
antisocial personality disorder 142, 143
anxiety **136–7**, 143
  and ADHD 130
  and focus 115
  medications 170
  emerging treatments 179, 180
  talk therapy 182
anxiolytics 170
applied behavioural analysis (ABA) 135
arithmetic **35**, 48
arousal *115*
artificial intelligence (AI) 39, 109, 126, 176–7, 179
artificial light **74–5**
Asperger's 134, 135
associative learning 16
astrocytoma *157*
attachment-based therapy 145
attention **32**
attention deficit hyperactivity disorder see ADHD
attention issues **114–15**, 122
auditory cortex 28, 32, *33*
autism 36, **134–5**, 162, 176
autoimmune disorders 140
autonomic foundations 61
autonomic nervous system 86
avoidant personality disorder 142, 143
axons *17*, *18*, 46

B
babies **42–3**, 44, 47, 56, 70, 78
basal ganglia 32–3, *33*, *85*, *129*, 137, 152–3
basal midbrain *15*
BDNF (brain-derived neurotropic factors) *17*, 82, 83, 90, 119
Beck Depression Inventory (BDI) 166
behaviour, and motivation **120–21**
beta waves 19
bilingualism 108
biofeedback 86, 180
biofeedback-based meditation 99
biological rhythms **26–7**
bipolar disorder 36, 75, 120, 138–9
blood flow: blood-brain barrier 14
  brain scans 12, *13*
  strokes 150, *151*
blue light 74–5
bonding 46, 47
borderline personality disorder (BDP) 142, 143
brain computer interfaces (BCIs) 13, 19, 86, 179
brain fog 50, 57, **116**, 123
brain mapping 13
brain scans 12, *13*, 39, 116, 167
brain waves 19
brainstem *15*, 152
brainstem glioma *157*
brainstorming 107
breathing 86, 90, 180, 183
Broca's area 28
bullying 67
burnout 116

C
caffeine 93
caffeine headaches *113*
cancer 91, 156
carbohydrates 78, 79
cardiovascular disease 55, 186
cardiovascular exercise 82, 159
cardiovascular system 30, 91
central executive network *106*
central nervous system 30
cerebellum *15*
  dysgraphia 133
  dystonia 152
  learning and memory 32–3, *33*
cerebral cortex 15
cerebrospinal fluid (CSF) 14
cerebrum 14
channel proteins 20
chemistry in the brain **20–21**
children **44–5**
  adverse events 77
  Covid-19 pandemic 126
  mental health 182
  social media use 88–9
  see *also* education
cholesterol 151
chronic traumatic encephalopathy (CTE) 158
chronotypes 26–7, 72
circadian rhythms 26, 75, 139
client-centred therapy 172
cluster headaches 112, *113*
coffee 93
cognition 60, 92
  ageing brain 55
  andropause 53
  HRT and 51
  water quality and 70
cognitive behavioural therapy (CBT) 81, 116, 128, 138, 145, 173, 182
cognitive biases 103–4
cognitive functions, changes in 121
cognitive processing therapy (CPT) 145
complex PTSD **144–5**
computed tomography (CT) 12, *13*, 167
computers: brain computer interfaces (BCIs) 13, 19, 86, 179
concussion 77, **158–9**, 168, 186
confirmation bias 103
connectomics 13
convergent thinking 106
cortisol: and stress 24, 25, 84
  anxiety 136
  benefits of nature 90
  biological rhythms 26
  loneliness and 80
  reproductive brain 46
Covid-19 pandemic 108, **126–7**, 182
cravings 128
creativity 90, **106–7**
CRISPR gene-editing 178, *178*
cytokines 20

D
deafness 162, 179
decision-making 48, **102–5**
deep brain stimulation (DBS) 152–3, *168*, 169, 174, *175*
default mode network (DMN) 80, 86, *106*
dehydration 70, *71*, 93
deliberate practice **96–7**
delusions 140–41, 154
dementia 120, **148–9**
  causes 148–9, 158
  language and 108
  light and 75
  loneliness and 80
  menopause and 50–51
  treatment and prevention 149
  types of 149
dendrites *17*, *18*, 19, 46
dependent personality disorder 143
depression **138–9**
  behavioural changes 120, *120*
  Covid-19 pandemic *127*
  emerging treatments 178, 179, 180
  implants 169
  light and 75
  loneliness and 92
  neurostimulation 174, 175
  talk therapy 182
dermatomes 30–31
diabetes 55, 151
dialectical behavioural therapy (DBT) 142, 145, 173, 182
diet see nutrition
digital therapeutics 177, *177*
disabilities 162
distractions, and memory 100
diurnal rhythms 26
divergent thinking 106
DNA 20, 178, *178*
doctors **164–5**
dopamine 20, *21*, 119
  and addiction 128
  and ADHD 131
  and OCD 137
  and Parkinson's 152
  and stress 84
  ageing brain 48
  benefits of nature 90
  flow state 97
  implants 169
  loneliness and 81
  medications 170
  mood and attention 114
  opioid addiction 22
  pathways *23*
  reproductive brain 47
  reward systems 88
dreaming 73
drugs **170–71**, 179, 182
Dunning-Kruger effect 105
dyscalculia 35, 132–3
dysgraphia 35, 132–3
dyslexia 35, 36, 39, 132–3
dystonia 152, 169

E
eccentric personalities 142
education 45, 108, 126, 133
electricity in the brain **18–19**
  brain scans 12, *13*
  neurofeedback 180, *181*
  neurostimulation **174–5**
  seizures 154–5, *155*
electroconvulsive therapy (ECT) 174
electrodes 169
electroencephalography (EEG) 12, *13*, 154, 167, *167*
emerging treatments **176–81**
emotions **22–3**, 46, 48, 63, 100
endorphins 84
energy, reduced levels 120, 123
ependymoma *157*
epigenetics 20
epilepsy **154–5**, 169, 170, 178
epinephrine (adrenaline) 20, *21*, 25, 136
erratic personalities 143
exercise 55, 81, **82–3**, 98, 151
exposure therapy 173
extroverts 37
eye movement desensitization and reprocessing (EMDR) 145
eyes 28, 75

F
family history, brain health **64**
fatigue **116**
fats, in diet 78
female brain *47*, 57
"fight-or-flight" response 24–5, 84
flashcards 101
flow state 96–7, *97*
focus **98–9**

foetus brain **42–3**, 46
folic acid (folate) 45, 56, 78
food *see* nutrition
forebrain *15*
forgetfulness **118–19**, 123
forgetting curves *101*
free association 107
Freud, Sigmund 30, 172
frontal cortex 17, 29, 33, *77*, *129*
frontal lobe 32, 35, 141
frontotemporal dementia 149
functional magnetic resonance imaging (fMRI) 12, *13*, 167
functional near infrared spectroscopy (fNIRS) 12, *13*

G
GABA (gamma-aminobutyric acid) 20, *21*, 128, 136, 170
Gage, Phineas 12
gene-editing 13, 178, *178*
gene therapies 178
generalized anxiety disorder (GAD) 136, 166
genetics 13, 20, 141, 178
gifted students 133
glioblastoma *157*
glioma 168
glucose 20
glutamate 20, *21*, 119, 128, 137, 139, 169
gluten free diet 79
goals, focus and productivity 98, 99
gonads 46
growth hormone 72
gustatory cortex 29
gut-brain axis **30–31**
gyri ("ridges") 14, *15*

H
hallucinations 140–41
headaches **112–13**, 122, 171
health **60–66**
hearing 28
heart disease 55, 77, 80, 151
Hebb, Donald 16
helmets 77, 159
hemicrania continua *113*
high intensity interval training (HIIT) 82
hindbrain 14, *15*, 38

hippocampus: and abuse 77
and addiction *129*
and worry 117
anxiety 136
autism 134
development of 45
education and 108
learning and memory 22, 32–3, *33*, 100
mental loops 123
neuroplasticity 17
post-traumatic stress disorders 144
reproductive brain 46
histrionic personality disorder 143
homunculus 14, *14*, 15
hormones 20
andropause **52–3**
and anxiety 136
biological rhythms 26
and dementia 148
gut-brain axis 30
headaches 113, *113*
hormone replacement therapy (HRT) 51, 57
light and 74
menopause **50–51**
in middle age 48
neuroplasticity 16
in pregnancy 46
puberty 46
stress hormones 24–5, 84
human immunodeficiency virus (HIV) 149
Huntington's disease 149, 152, 178
hydration **70–71**, 93
hyperactivity 130–31
hyperfocus 130, 131
hypertension 77
hypnosis 92
hypothalamus *15*, 22–3, *24*, 25, 26
hypothalamus-pituitary-gonadal axis (HPG) 46
hypothalmic-pituitary axis (HPA) 24, *24*, 25, 84, 86

I
illusions 29, *29*
immune system 25, 30, 63, 81, 86, 91, 140
implants *168*, 169

"in-group vs out-group bias" 105
inflammation 45, 76, 81, 82, 91, 108, 158
infradian cycles 26
injuries 64–5, 67, 77, **158–9**, 180, 186
inner worlds **36–7**
insula 23
insulin 26
intelligence 54, 57, 76
see also artificial intelligence (AI)
International Classification of Diseases (ICD) 166
interpersonal therapy 182
intraparietal sulcus 35
introverts 37
intrusive thoughts **117**
invasive procedures **168–9**
IQ 76
isolation 120, 182

J
judgement 48

K
ketogenic diet 155

L
language 32, 34–5, 45, 49, 62, 108, 132
laughter 87
lead, air pollution 76
learning **32–3**, **100–101**
learning differences 36, **132–3**
"left-brain" people 38
left-handedness 39, 162
Lewy Body dementia 149
lifestyle 51, 53, 57, 66, 99, 101, 116, 117
light **74–5**
limbic system **22–3**
addiction 128
and anxiety *137*
and planning 38
and stress *85*
creativity 106
decision-making 102
development of 45
lithium 170
"little person" 14, *14*, 15
loci, theory of 100
loneliness 66, 80, 92, 126, 182
long-term potentiation (LTP) *17*

M
magnetic resonance imaging (MRI) 12, *13*, 167
magnetoencephalography (MEG) 12, *13*
male brain *47*, 57
mania 75, 138
mathematics **35**
medical teams **164–5**
medications **170–71**, 179, 182
meditation 86, 87, *87*, 93, 99
medulla *15*
medulloblastoma *157*
melanin 75
melatonin 20, 26, 74
memory **32–3**, **100–101**
cognitive biases 104
forgetfulness **118–19**, 123
in middle age 48, *49*
storage 19
meningioma *157*, 168
menopause **50–51**, 57, 118, 149
mental health 88, *89*, 122, 126, **182–3**
see also specific types of mental disorder
mental loops 123
mental models 96
mesocortex *15*
metabolic pathways 20
midbrain 14, *15*, 38
middle age **48–9**
migraines 112, *113*, 171
mind-body connection 20, 23, **24–5**
mind mapping 107
mindfulness 81, 86–7, *87*, 93, 99, 107, 177
mindfulness-based therapies 173
mindreading 39
minerals 45, 56, 78, 109
mnemonic devices 101
mood challenges **114–15**
mood disorders 121, 122, **138–9**, 170
mood regulation 63
morning larks 27
Moro reflex 42
motivation **23**, 63, **120–21**
movement disorders **152–3**, 169, 174
muscles 62, 82, 86
music therapy 153
myelin 42, 43, 55

N
narcissistic personality disorder 142, 143
"natural experiments" 12
natural light **74–5**
nature, benefits of **90–91**
navigation 57, 62, 63
nearsightedness 162
negative feelings 48, 66, 67, 90, 114, 122
negative thoughts **117**
neocortex 14, *15*
nervous system 91
gut-brain axis **30–31**
neural tube defects 56, 78
neurodegenerative diseases 75, 158
neurodiversity **36–7**, 135, 141, 142, 176
neurofeedback 99, 179, 180, *181*
neurogenesis *17*
neurological assessments 118
neurologists 164
neurons: electrical signals 18–19, *18*
foetus brain 42
neuroplasticity **16–17**, 38, 45, 177
older brains 55
seizures 154
neuropeptides 112
neuropharmacology 13
neuroplasticity **16–17**, 38, 45, 177
"neuropsychological assessments" 12–13
neuropsychologists 166–7
neuroscientists 12
neurostimulation **174–5**
neurotransmitters 13, 19
and addiction 128
and anxiety 136
and depression 138
and forgetfulness 119
and OCD 137
biopolar disorder 139
chemical structures *21*
chemical synapses 20
gut-brain axis 30
implants 169
loneliness and 81
medications 170
in middle age 48
mood and attention 114
nature and 90
older brains 55
stress and 84
neutrotrophic factors 46
NHS talking therapies 172
night owls 27, 72–3
nootropics 170
norepinephrine (noradrenaline) 20, *21*, 24, 84, 114, 136, 138, 170
novelty exposure 107
nucleus accumbens 22, 23, 88, 128, *129*
nutrition: and strokes 151
babies 56
deficiencies **78–9**
"smart" brain foods 109
young brains 45

O
obsessive compulsive disorder (OCD) 117, 123, 136, **137**, 174, 179
obsessive compulsive personality disorder 143
occipital temporal cortex 132
oestrogen 46, 50
older brains **54–5**, 57, 78
olfactory cortex 29
oligodendroglioma *157*
omega-3 fatty acids 45, 56
opioid system 128
opioids 22, 170, *171*
optic glioma *157*
optical illusions 29, *29*
orbitofrontal cortex (OFC) 102
out-of-body experiences 154
overconfidence 103
overload **116**
overthinking **117**
oxidative stress 78
oxytocin 46, 47, 81

P
p-tau 217 119
pain 30
emerging treatments 179, 180
headaches **112–13**, 122, 171
hypnosis and 92
neurostimulation 174, 175
pain management 169, 170, *171*
paleo diet 79
panic attacks 136, 170, 183
papillary tumours *157*
paranoid personalities 142

paraplegic patients 19
parasympathetic nervous system (PSNS) 24, 25, 91
parenting 46, 47
parietal cortex 106
parietal lobe 28–9, 32, *33*, 35, 133
Parkinson's disease 67, 149, 152–3, *153*
  injuries and 158
  treatments 169, 174, 178
"peak-end rule" 104
peak performance techniques **96–7**
perception **28–9**, 62
perimenopause 50, *50*
peripheral nervous system 30
personality disorders **142–3**
pesticides 76
phobias 136
pineal gland *74*
pituitary adenoma *157*
pituitary gland *24*, 25, 46
pollution 76
Pomodoro technique 98
pons *15*
positron emission tomography (PET) 12, *13*, 167
post-traumatic growth (PTG) 67
post-traumatic headaches *113*
post-traumatic stress disorder (PTSD) 117, 123, **144–5**
prefrontal cortex: and addiction 128
  and anxiety 136
  and relaxation 86
  and stress *85*
  and worry 117
  autism 134
  benefits of nature 91
  creativity 106
  decision-making 102
  deliberate practice 96
  in adolescence 44–5, *44*
  learning and memory 32–3, *33*
  loneliness and 80
  mental loops 123
  older brains 55
  post-traumatic stress disorders 144
  reproductive brain 47
  reward systems 88
  schizophrenia 141
pregnancy 42, 46, 70, 78
premenopause *50*
premenstrual dysphoric disorder (PMDD) 139
problem-solving strategies 107
productivity **98–9**
progesterone 50
prolactin 46, 47
prolonged exposure (PE) 145
protein 78
psychedelics 179
psychoanalysis 172
psychologists 166–7
psychotherapy 17
psychotic disorders 120
puberty 45, 46

R
randomized control trial (RCT) 163, *163*
reading **34–5**
rebound headaches 113, *113*
reflexes 42
relationships: abuse 76–7
  brain health 61
  isolation 120, 182
  social health **80–81**
  young brains 45
relaxation **86–7**
repetitive thoughts 123
reproductive brain **46–7**
resistance training 82
reticular activating system (RAS) 32, *33*
reward systems 23, 88, 128, 129
"right-brain" people 38
right-handedness 39
robotics 109
Rogers, Carl 172
rooting reflex 42

S
salience network *106*
schizoid personalities 142
schizophrenia 120, **140–41**, 183
schizotypal personalities 142
schools 45, 108, 126, 133
schwannoma *157*
screening **166–7**
seasonal affective disorder (SAD) 139
secondary brain 101
seizures 154–5, *155*, 169, 180
senses **28–9**, 62
  synaesthesia 36–7, *37*
  see also individual senses
serotonin 20, *21*
  and depression 138
  and OCD 137
  antidepressants 170
  benefits of nature 90
  gut-brain axis 30
  loneliness and 81
  medications 170
  mood and attention 114
sexual dysfunction 53
sight 28
single-photon emission computerized tomography (SPECT) 12, *13*, 167
sinus headaches 112, *113*
skills, honing 97, *97*
skin-brain connections 30–31, *31*
sleep **72–3**, 92, 93
  and loneliness 80
  and strokes 151
  babies 43
  and blue light 75
  emerging treatments 180
  lack of 77
  melatonin 20
  power naps 93
  sleep-wake cycle 26
"smart" brain foods 109
SMART goals 98
smell, sense of 29
smoking 151
social anxiety disorders 120, 136
social health **80–81**, 92
social media **88–9**
social reward networks *135*
sodium-potassium pumps 18
somatosensory system 28–9
sounds, hearing 28
spinal cord *15*
spinal cord stimulation (SCS) 174, 175
spinal headaches *113*
spine, nervous system *31*
SSRIs (selective serotonin reuptake inhibitors) 170
stem cell research 13
stimulation, young brains 45
"streetlight effect" 104
stress 63, 67, **84–5**
  and forgetfulness 118
  and loneliness 81
  and strokes 151
  gut-brain axis 30
  mental loops 123
  mind-body connection **24–5**
  post-traumatic stress disorders 117, 123, **144–5**
  stress hormones 24–5, 80
  stress management
    techniques 116
  stress response 20, 84
strokes 17, 80, **150–51**, 155, 175
structure of brain **14–15**, *15*
sucking reflex 42
suicidal thoughts 121, 182
sulci ("grooves") 14, *15*
sunlight 74
supplements 109
suprachiasmatic nucleus (SCN) 26, 74
surgery **168–9**
sympathetic nervous system (SNS) 24–5
synaesthesia 36–7, *37*
synapses 16, *16*, *18*, 19, 20, 55
synaptic proteins *17*

T
talk therapy **172–3**, 182
taste, sense of 29
teenagers see adolescence
temporal lobe 28, 32, 34–5, *34*, 106
tension headaches 112, *113*
testosterone 46, 52–3, *52*
tests **166–7**
thalamus *15*, 28–9, 32, *33*, *129*, 141
therapeutic teams **164–5**
therapists **172–3**
theta waves 19
thunderclap headaches *113*
tics 152
time blocking 98
tiredness **116**
touch, sense of 28–9
Tourette's syndrome 152
transcranial alternating-current stimulation (tACS) 174, 175
transcranial direct-current stimulation (tDCS) 174, 175, *175*
transcranial magnetic stimulation (TMS) 174, *175*
transcranial pulsed current stimulation (tPCS) 175
transcutaneous nerve stimulation (TENS) 174, 175
transgender brains 57
transient ischaemic attacks (TIAs) 150
trauma 144, *145*
trauma-focused therapy (TFT) 145
treatments **162–3**
  see also specific treatments
tremors 152, 153, 169
trigeminal nerve 112
tumours **156–7**, 168
"twice exceptional" 133

U
ultradian cycles 26

V
vagus nerve stimulation (VNS) 169, 174, *175*
vascular dementia 149
vascular system 77–8
vegan diet 79
ventral striatum 88
ventral tegmental area (VTA) 22, 23, *129*
ventricles 141
video games **88–9**, 177
virtual reality 177
visions 138
visual cortex 28, 32, *33*, 34, 73, 100
vitamins 45, 56, 75, 78, 109
vocabulary 49

W
walking 90, *91*
water, drinking **70–71**, 93
Wernicke's area 28
willpower 183
World Health Organization (WHO) 22, 80, 126, 166, 183
worry **117**
writing **35**

Y
Yerkes-Dodson law 115
yoga 87
young brains 56