COPYRIGHTED MATERIAL

“Sitting on our shoulders is the most complicated object in the known universe.”

MICHIO KAKU
Theoretical physicist and futurist (1947–)

Our Brain

ABOUT THIS CHAPTER

The brain is the basis of everything we do: how we behave, feel, remember, pay attention, create, change, influence and ultimately live. Learning about how our brain functions is an important starting point to understanding why we do what we do.

Even though it only weighs around one and a half kilograms, our brain is complicated. With the advent of neuroimaging techniques we are now able to see inside the brain and explore its function and structure in greater depth. But despite new advances in neuroscience, neurobiology and neuropsychology, the brain remains the most mysterious, complex and relatively unknown organ in the human body.

This chapter provides an introductory overview of the main structures and functions of the human brain. It explains how our brain helps us respond to the world around us and keeps our system in balance. Some insights are offered into male/female brain differences, whilst also acknowledging the influences of our environment and upbringing.

As we begin to understand more about how our brain works, we become more aware of our own thoughts, responses, behaviours and emotions. We also become better equipped to get the best out of our brainpower in the future.

Part 1: The science explained

The key function of our brain is to keep us alive. This means that our brain needs to be able to anticipate what is safe or harmful in our environment.

In other words, our brain is our *personal prediction machine*. It is constantly scanning and processing the world around us to help us respond appropriately.

Why we need to keep it all in balance

The brain maintains a finely tuned internal balance in order to regulate our heartbeat, breathing, temperature, water, hormonal release and sugar levels. This internal balance is known as *homeostasis,* meaning 'same state'.

Our internal body environment is kept steady and stable despite changes in our external surroundings. This balancing act works on what is called a *negative feedback loop* (see Figure 1.1): when the level of something rises, our brain's control systems reduce that level, and when the level of something falls, our brain's control systems raise that level.

For example, if we are cold, we shiver in order to generate heat, and if we become too hot, we sweat in order to cool down.

Our brain works hard to maintain this balance and to keep our system functioning effectively.

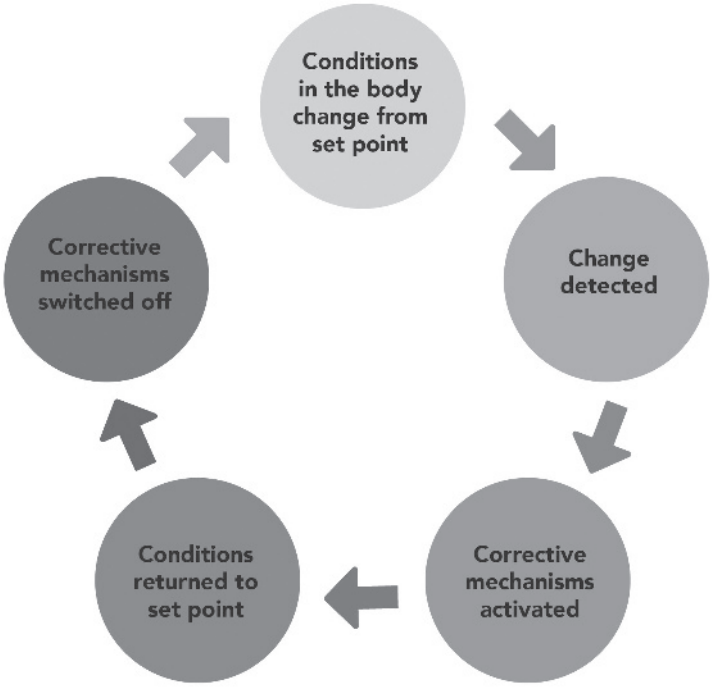


FIGURE 1.1: The negative feedback loop

Our brain, neurons and synapses

Our brain represents just two percent of our total body weight and is made up of approximately 100 billion nerve cells, which are known as *neurons*.

Each neuron can make between 1,000 and 10,000 connections, or *synapses,* with other neurons. Our brain's ability to form new connections, constantly reorganising itself and changing its pattern and shape, is known as *neuroplasticity*. We have two different types of neurons – *sensory* and *motor*:

Sensory neurons carry information from our sensory organs – eyes, ears, nose, tongue and skin – to the brain.

Motor neurons carry messages away from the brain and spinal cord to our muscles.

Our brain has three main parts: *forebrain, midbrain* and *hindbrain*. The midbrain and hindbrain make up the brain stem and connect the forebrain to the spinal cord. The forebrain contains the *cerebrum,* the largest part of the brain, which plays a critical role in processing information.

Our four lobes . . .

The **cerebrum** is divided into four *lobes* (see Figures 1.2 and 1.3). Although these are all interconnected, each lobe is associated with different functions.

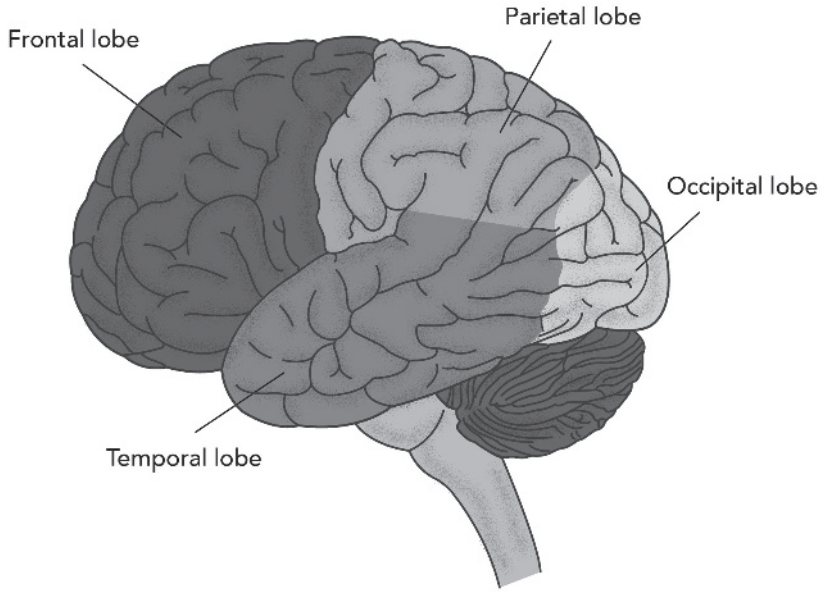


FIGURE 1.2: The lobes of the brain

Frontal lobe	Processes higher cognitive functions and decision-making. This is the centre of our brain's executive functioning and manages complex mental and behavioural responses to the environment.
Temporal lobe	Controls our hearing and processes memories, integrates them with our senses and emotions and regulates our endocrine system, which releases our hormones.
Parietal lobe	Processes information about temperature, taste, touch, movement, reading and spatial orientation.
Occipital lobe	Primarily responsible for vision and the interpretation of information taken in by the eyes.

FIGURE 1.3: Our four lobes

Our lobes work together to enable our brain to operate as a whole and to adapt constantly to keep us functioning. If we lose a sense such as sight, another sense such as hearing gets stronger. The *seeing* part of the brain is then used to process sound.

. . . and two hemispheres

Most mental functions are distributed across the *right* and *left* sides, or *hemispheres,* of our brain. Certain mental processes and tasks are specialised to either one hemisphere or the other (see Figure 1.4). This is known as *lateralisation* of brain function. Scientists believe that this is our brain's way of being more efficient: by avoiding duplication, we optimise our available brainpower.

Our knowledge of the brain's hemispheres can be largely credited to the work of Dr Roger Sperry during the 1960s. Dr Sperry examined the way our brain's hemispheres operate both independently and together and, in 1981, was awarded the Nobel Prize in Physiology or Medicine for his work in this area.

The **left hemisphere** normally directs logical, analytical, mathematical and verbal tasks.

The **right hemisphere** is generally more concerned with music, emotion and tonality, facial recognition, visual imagery and abstract information.

The right hemisphere controls the muscles on the left side of our body, while the left hemisphere controls the muscles on the right side. Damage to one side of the brain, such as that caused by a stroke, affects the opposite side of the body.

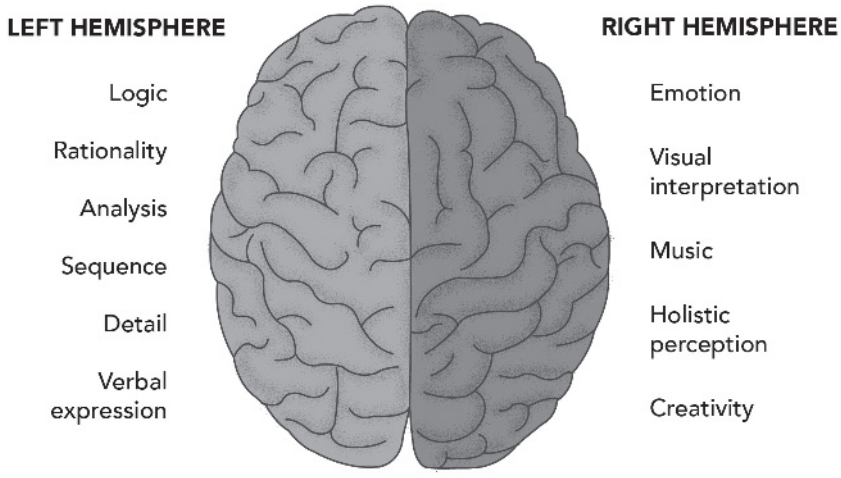


FIGURE 1.4: Our two hemispheres and their roles

Connecting the two hemispheres is a network of fibres, called the *corpus callosum,* which enables information to be carried between the hemispheres. The primary function of the corpus callosum is to ensure that our brain functions as one integrated and cohesive unit.

How neurons communicate with each other

All of our neurons pass on information to other neurons. In order to do this, our brain communicates on an electrical as well as a chemical level, involving ions such as sodium, potassium and calcium. Communication between neurons is the core of all our thoughts, emotions and behaviours.

Any new experience stimulates an electrical impulse within a neuron. Electricity cannot travel across a gap or space, called the *synaptic cleft,* so when this impulse reaches the end of the neuron the information has to be relayed by chemicals, known as *neurotransmitters.*

Neurotransmitters are stored in small compartments called *vesicles.* Each vesicle tends to hold one type of neurotransmitter. The neurotransmitters travel in their vesicles to the end of the neuron where they wait to cross over the gap. At the right time, the neurotransmitter is emptied into the gap and travels across to the other neuron. When neurotransmitters travel between neurons, they form a connection with another neuron (see Figure 1.5).

All of this happens with impressive speed and precision.

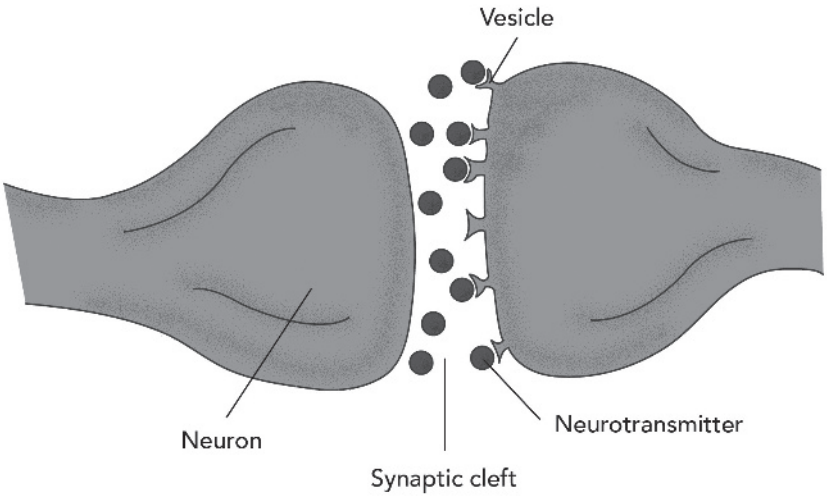


FIGURE 1.5: Neurons and neurotransmitters

Neurotransmitters affect our mood, memory and wellbeing. They are effectively our *chemicals of emotion.*

There are two types of neurotransmitters: *excitatory* and *inhibitory*.

Excitatory neurotransmitters stimulate the brain.

Inhibitory neurotransmitters calm the brain and balance brain stimulation.

The impact of neurotransmitters on our health is the focus of ongoing scientific research. Problems with even minor aspects of their release process from one neuron to another have been linked to many brain disorders and nervous system diseases, including depression, autism, schizophrenia, dementia and epilepsy.

The role and symptoms of deficiency of some of these neurotransmitters are described in Figure 1.6.

Chapter 12, Our Brain and Lifestyle, discusses how certain foods boost the performance of neurotransmitters in our brain.

Our nervous system

The brain controls our nervous system, which regulates how we respond and adjust to the world around us.

Neurotransmitter	Role	Some symptoms of deficiency
Serotonin	Inhibitory neurotransmitter. Plays an important role in regulating mood, happiness, relaxation, appetite, memory, bowel function, learning and hormonal release.	Depressed mood, anxiety, panic attacks, low energy, sleeping problems, feeling tense and irritable, impaired memory and concentration.
Oxytocin	Also known as the *cuddle chemical* or *moral molecule*. Plays a key role in maternal bonding, childbirth, social affiliation and increases romantic attachment and empathy. Makes us more sensitive to social cues around us.	Anxiety, stress, feelings of disconnect with others, depression, loss of appetite, greater sensitivity to pain. Used to accelerate childbirth and improve social engagement in people with autism.
Dopamine	Both an excitatory and inhibitory neurotransmitter. Responsible for movement, memory, pleasurable reward, attention, desire and drive to get things done. Known as our *motivation molecule*. Controls movement and posture.	Memory problems, poor concentration, difficulty initiating or completing tasks, lack of energy, lack of motivation, addictions, cravings, compulsions, a loss of satisfaction and libido. Too little dopamine is implicated in Parkinson's Disease.
Glutamate	Major excitatory neurotransmitter in our brain. Involved in cognition, memory and learning.	Insomnia, problems concentrating, mental exhaustion and depleted energy.
GABA	Inhibitory neurotransmitter. GABA (*gamma*-aminobutyric acid) acts as a natural sedative and tranquilliser and calms nervous activity. Contributes to motor control and vision.	Anxiety disorders, racing thoughts, bipolar disorder, mania, poor impulse control, panic attacks, cold hands and shortness of breath.
Acetylcholine	Widely distributed excitatory neurotransmitter. Major impact on wakefulness, attentiveness and arousal. Needed to turn short-term memories into long-term ones. Released to activate muscles. (Botox is a neurotoxin that blocks the effect of acetylcholine, preventing the facial muscles from moving.)	Low energy levels, memory loss, learning problems, muscle aches, cognitive decline. People with Alzheimer's Disease have altered levels of acetylcholine. Also implicated in Parkinson's Disease.
Noradrenaline	Excitatory neurotransmitter. Triggers changes in the body in response to stress (increased oxygen, heart rate and glucose) to raise our alertness and *fight or flight* capacity. Important for attentiveness, emotions, dreaming and learning.	Depression, loss of alertness, memory problems, lack of energy, focus and motivation.

FIGURE 1.6: Some neurotransmitters and their roles

Function of the nervous system

The nervous system has three main functions (see Figure 1.7):

1. *Sensory*	passing information from our senses to the central nervous system for processing.
2. *Integrating*	using the sensory signals for decision-making or the formation of new memories.
3. *Motor*	activating our muscles and glands.

FIGURE 1.7: Functions of our nervous system

There are two parts to our nervous system (see Figure 1.8):

1. *Central nervous system* (brain and spinal cord).

2. *Peripheral nervous system* (cranial nerves branching from the brain, spinal nerves branching from the spinal cord and rest of the body).

Messages are carried between the central nervous system and the peripheral nervous system to activate the muscles and glands.

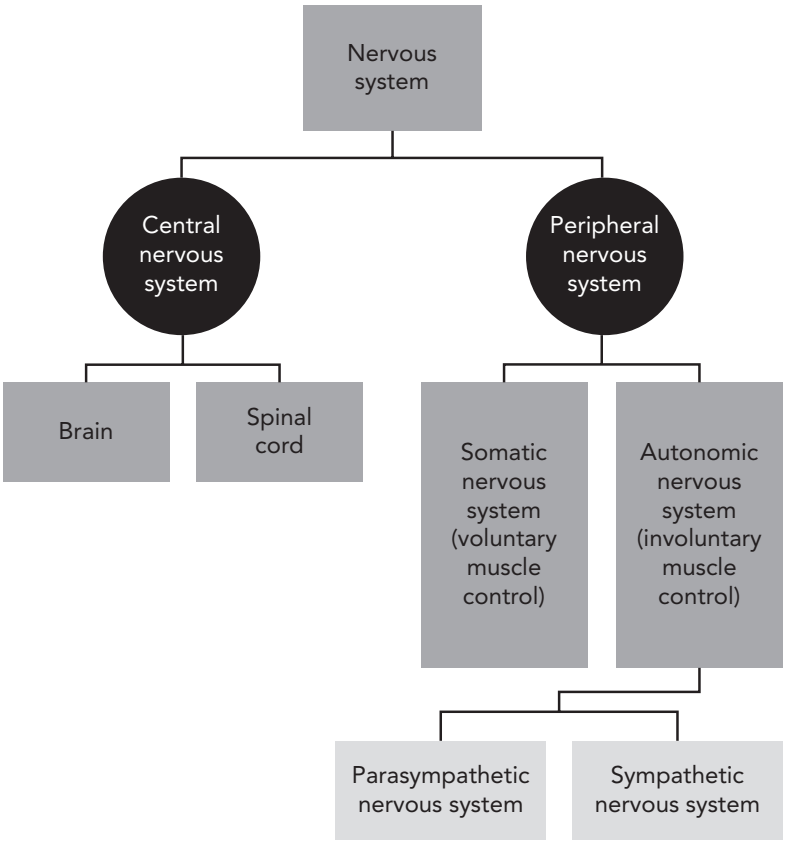


FIGURE 1.8: Our nervous system

Central nervous system (CNS)

The **central nervous system** (CNS) is made up of the brain and the spinal cord and is composed of *grey* and *white matter* (see Figure 1.9). **Grey matter** refers to the neurons, and **white matter** refers to the *axons,* or nerve fibres, that carry impulses between neurons. Axons are white because they are coated with a fatty substance called *myelin,* which gives them their colour. (The role of myelin is discussed later in this chapter.)

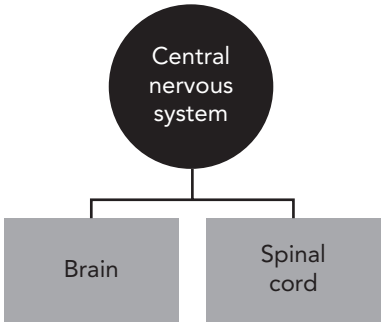


FIGURE 1.9: Our central nervous system

The spinal cord is a single continuous structure running from the brain, through the base of the skull and then down the spinal column.

The CNS controls our responses to the environment. It processes inputs that we receive through our senses and then communicates with the rest of our body by sending messages from the brain through the nerves branching off the spine that make up our peripheral nervous system (PNS).

Whenever we want to move our body, our CNS translates this intention into chemical and electrical messages that provide instructions for our muscles to activate.

If our CNS is injured or affected by disease, we can suffer permanent loss of function or disability.

Peripheral nervous system (PNS)

The **peripheral nervous system** (PNS) works with the CNS to process information from our environment (see Figure 1.10).

The PNS carries information to and from the CNS via our peripheral nerves and regulates our body temperature, blood pressure and thirst. Unlike the CNS, the PNS is not protected by bone. Damage to the CNS can cause damage to the whole body, whereas damage to the PNS is often localised.

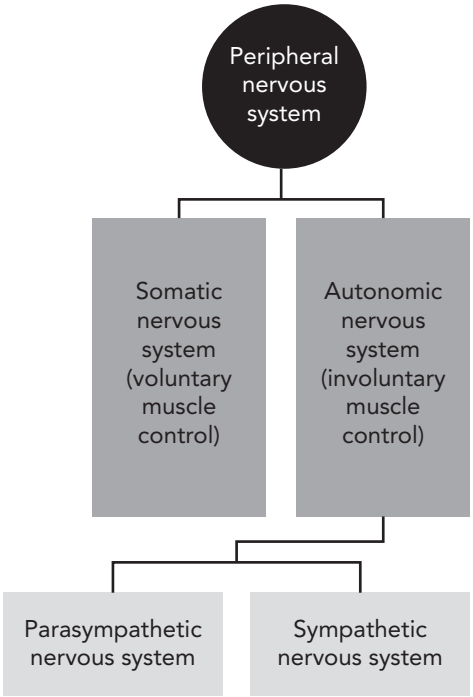


FIGURE 1.10: Our peripheral nervous system

There are two aspects to the peripheral nervous system:

1. The *somatic nervous system* communicates with our senses and is involved in voluntary muscle movements, such as learning ballet or football. **Somatic nerves** come predominantly from the spinal cord and stimulate the contraction of skeletal muscles.
2. By contrast, the *autonomic nervous system* regulates all the involuntary but life-critical activity of the internal organs and hormones – essentially everything internal that we never even think about. **Autonomic nerves** come from both the spinal cord and the brain and help to maintain homeostasis via two systems: the *parasympathetic nervous system* (*rest and digest*) and the *sympathetic nervous system* (*fight or flight*). See Figure 1.11 for more detail.

Parasympathetic nervous system *Rest and digest* This forms the body's response when the body is resting and recovering.		**Sympathetic nervous system** *Fight or flight* This forms the body's response to acute, short-term stress.
Parasympathetic response	**Area of Body**	**Sympathetic response**
Pupils constrict	Eyes	Pupils dilate
Saliva production increases	Salivary glands	Saliva production reduces
Mucus production increases	Nose	Mucus production reduces
Heart rate slows down	Heart	Heart rate increases
Bronchial muscle contracts	Lungs	Bronchial muscle relaxes
Gastral juices increase	Stomach	Gastral juices reduce
Normal function	Liver	Glucose increases
Urine increases	Kidneys	Urine decreases
Normal function	Adrenal glands	Adrenaline is released

FIGURE 1.11: Our autonomic nervous system

What happens when we activate the autonomic nervous system?

The two parts of the autonomic system (**parasympathetic** and **sympathetic**) are designed to work together in balance: when one part is working, the other stops. Too much activity on one side can lead to ill health.

Although our autonomic nervous system is continually on, functioning day and night, we are not conscious of it working on our behalf.

Our nervous system is vital for our ability to function in every way. It controls all the muscles, tissues and organs in our body. Our brain, spinal cord and peripheral nerves are coated with a protective layer of protein and fatty substances, called a *myelin sheath*. This coating process is known as *myelination*.

Myelin is essential for the proper working of our nervous system. When myelin is damaged, nerve impulses are affected, leading to diseases such as multiple sclerosis. We can promote the health of our myelin sheath by eating a healthy diet, as explained further in Chapter 12, Our Brain and Lifestyle.

Part 2: Impact on our daily life

Do women and men have different brains?

There is considerable debate among researchers as to whether women and men have different brains. Scientists are divided over whether any differences in the brain are the result of our genetic make-up (*nature*) or whether, instead, they are the consequence of the family and culture we are raised in (*nurture*). In fact, a recent study has even suggested that there are no real brain differences between the sexes, and that any brain differences emerge because of the significance we give them.[1] This is a view supported by Professor Gina Rippon who refutes sex-linked brain differences and warns against stereotyping in a world where children are subjected to gender differences from an early age.[2]

Even so, from a biological point of view, men's brains are, on the whole, 10 to 12% bigger than women's brains. But a bigger brain does not necessarily mean a more intelligent brain (see Figure 1.12)! Men's brains tend to be bigger because they control a larger body mass and musculature than those of women. Although all human brains begin as female, there is a release of hormones that then determines the sex of the foetus. Around six weeks after conception, the brain of the male foetus will experience a surge of testosterone, which stimulates growth of the *hypothalamus,* the area of the brain that produces and controls our hormones.

Studies have shown that serotonin is synthesised faster in the male brain than the female brain.[3] This may explain why there are more incidences of depression in women and why women, particularly in times of stress, may be drawn to food rich in tryptophan, an amino acid that enables the production of serotonin, such as chocolate.
The *anterior cingulate cortex*, which regulates thinking and emotion and is involved in detecting errors, is larger in the female brain. Dr Louann Brizendine calls this the 'worry-wort centre'.[4]
The *amygdala* and the *hypothalamus*, which are involved in the body's response to fear and danger, are sensitive to *testosterone* and they both grow larger in young men. This explains why many men are more attracted to competitive sport and why sexual desire can differ in young men and women.
Oxytocin has a different effect on the way men and women process information about other people: it increases bonding and prosocial behaviour in women, and more protective instincts in men.[5]
Although the notion of pain is highly subjective, it does appear that women are more sensitive to pain than men and suffer from pain-related conditions more frequently.[6] Men produce more *endorphins* than women, which could explain men's greater tolerance of pain. Chapter 2, Our Brain and Emotion, discusses endorphins in more detail.
Men's navigational skills and spatial judgement are more effective compared to women's. Men also consistently outperform women on mental rotation tasks unless they suppress their emotions, in which case they perform identically.[7] These differences have been linked to both men's higher levels of testosterone[8] and a larger male parietal lobe.[9]

FIGURE 1.12: Some reported differences between the sexes

One of the biggest differences between male and female brains has been observed in the *hippocampus,* which stores personal memories (explained in more detail in Chapter 3, Our Brain and Memory) and is engaged in processing memories into words. The hormone oestrogen has a direct effect on hippocampal formation and performance. This may explain why women generally excel at remembering words, objects, pictures and faces.

Magnetic resonance imaging (MRI) scans have shown that women have more connections in the corpus callosum, which connects the two hemispheres, integrating information from both sides.[10] However, it is worth mentioning that the role of the corpus callosum has been much debated, with other studies claiming that any male/female differences are spurious or insignificant.

Diffusion tensor imaging (DTI), a water-based imaging technique, has also looked at pathways connecting the different regions of the brain in men and women. The results show that men's brains (illustrated in the top half of Figure 1.13) display front-to-back connectivity *within* the hemispheres, moving between perception and decision-making. Women's brains (illustrated in the bottom half of Figure 1.13) are wired more laterally, between the hemispheres, suggesting greater communication between analysis and intuition.

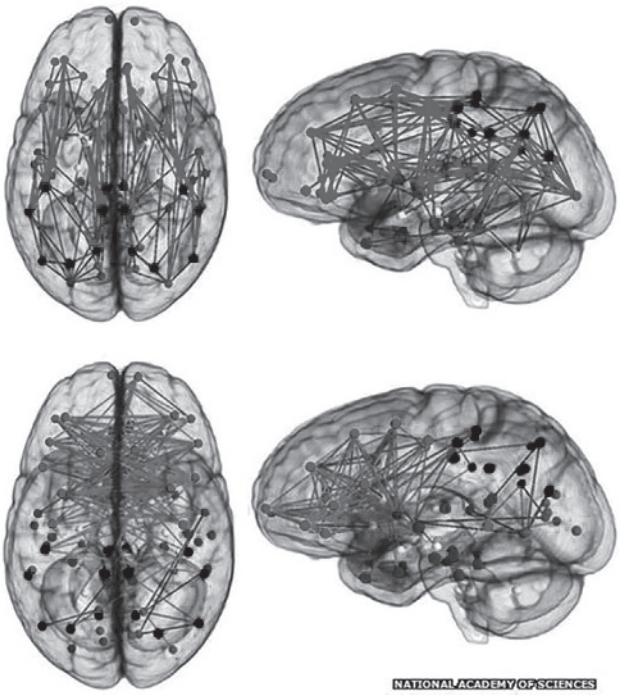


FIGURE 1.13: Are men's and women's brains wired differently?
Credit: Dr Ragini Verma, *Proceedings of the National Academy of Sciences.*[11]

It is nevertheless important to note that these differences emerge only after adolescence, which bolsters the notion that our brains are malleable and adaptable, particularly during childhood.

Male/female differences may therefore develop or be encouraged over time as boys and girls are treated differently within the cultures in which they are raised.

Why are both nature AND nurture important?

We each represent a unique combination and interplay of factors, acquired from early childhood and life experiences, together with our genetic blueprint or inherited tendencies.

And so, even though we may be born with a physiological or psychological predisposition, our upbringing, especially during the early years, plays a critical role in determining whether certain behavioural traits will emerge or remain dormant.

This means that, while male/female biological differences have been observed through various studies, both nature *and* nurture play a combined role in establishing how we develop. Because the brain is a muscle, which like other muscles in our body needs to be kept active, it is strengthened or weakened through reinforcing or reducing certain patterns of brain activity. Throughout our life we can continue to shape our brain by learning a range of skills, embracing new ideas and meeting different people.

What difference does being right- or left-handed make?

Most of us have a dominant hand that we use. We live in a right-handed world, with only around 10% of the total human population being left-handed. There are a number of theories that attempt to explain why this is the case, one of which is that right-handed dominance is an evolutionary adaptation that has been passed down over time.

Culture plays a significant role in determining which hand we use; for example, certain religions do not allow the left hand to be used for eating food or for ceremonial rituals.

Even though the hemispheres control our body diagonally, this does not mean that left-handed people are necessarily more *right-brained* or more creative, or that right-handed people are more *left-brained* or more logical. The complex way in

which the hemispheres work together cannot be explained by simply saying that we are governed by either one side or the other.

Most of us may naturally have a preference towards one side and we are influenced by the way we are taught and tested. For example, a large number of education systems cater more for the left hemisphere, focusing on analysis and logic rather than on creativity and the arts.

But in reality, we all benefit from the combined functioning of both hemispheres.

Why do adolescents do what they do?

Over the last 10 to 15 years, research into the teenage brain has gained traction. As mental illness becomes less stygmatised and more socially recognised, scientists are now working hard to understand how and why the brain handles – or struggles to handle – certain transitions throughout life.

The adolescent brain undergoes a significant period of growth and development. The pre-frontal cortex (see Figure 1.14), in particular, is still being remodelled and is not fully formed until around our mid-twenties. This area coordinates our brain and body and our higher-level executive functioning: judgement, personality, impulse control, reasoning, long-term planning, intellect, mood, social skills, conscience and empathy. In other words, we expect teenagers to make important decisions regarding their education and future at a time when they are least equipped to do so.

Although adolescence is an important period of development, research into the adolescent brain is still relatively new. Neuroscientists such as Professor Sarah-Jane Blakemore offer valuable insights into our brain structure and function during this stage of life.[12] Studies show that, as teenagers pursue increased autonomy and develop a greater sense of self, they push against the boundaries around them, heightening their susceptibility to risk-taking and peer pressure. Their quest for independence and social inclusion at a time when their brain is still growing makes them vulnerable to danger and injury, which is a leading cause of death among this age group.[13] For parents and caregivers, it is important to strike the right balance between freedom and safety in order to manage the complex interplay between adolescent neurological changes and a demanding environment.

During our adolescent years, our neural connections grow and any connections that we do not use are pruned to help the brain become more efficient. This is a process called *synaptic pruning*.

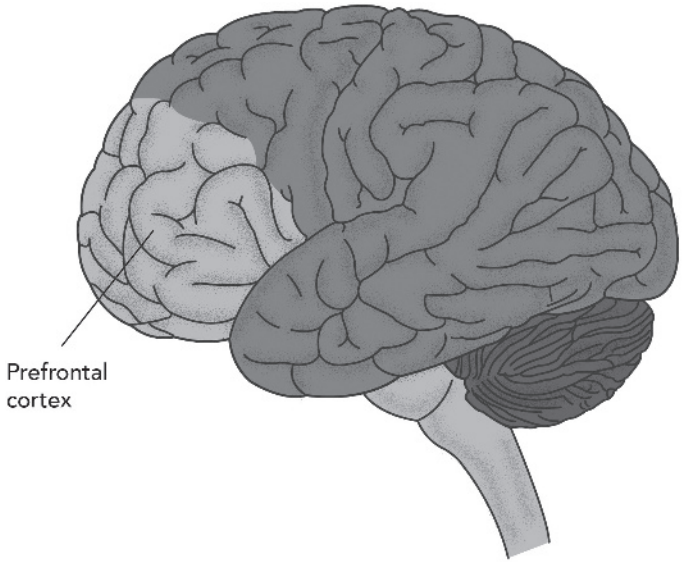


FIGURE 1.14: The prefrontal cortex

At the same time as this synaptic pruning takes place, myelination occurs. As explained earlier in this chapter, the process of myelination coats our nerves with a protective fatty substance called myelin, which facilitates the transmission of signals between neurons. As the teenage brain remodels itself, the remaining connections are now able to communicate with each other with more efficiency and speed.

As a protective measure against the teenage propensity to become distracted or engage in risky behaviour, particularly in front of peers, Ford's MyKey system is designed for parents to limit the speed at which their children drive. The system interfaces with the computer systems on board and places restrictions on drivers. Speed is not the only restriction; car audio can be limited as well.

We mature as our brain improves its ability to integrate and transfer information among its different regions and, as a result, we are able to control our emotions and impulses more consistently.

Part 3: Stories and top tips

Was Einstein's brain different?

The brain of Albert Einstein has been the subject of much debate. Scientists have been intrigued to know whether Einstein had a brain different to the general population.

Seven-and-a-half hours after his death, Einstein's brain was removed by scientists who then studied its structure. They discovered that it had a greater number of connections than the brains of other people of a similar age, suggesting that Einstein had continued to exercise his brain, hence delaying the degeneration that would normally occur during the ageing process.

The main difference in Einstein's brain was in an area of the parietal lobe known as the *inferior parietal region*, used for spatial awareness, mathematical thought and motor imagery. This region was so developed on both sides that his brain was 15% wider than other brains.

As well as enlarged parietal structures, Einstein's brain had a thicker corpus callosum connecting the two hemispheres, particularly in an area called the *splenium,* which facilitates communication among all four of the brain's lobes.[14]

Einstein's genius was therefore likely to have been a result of both a well-functioning brain and constant mental challenges throughout his lifetime.

Should young children head footballs?

There is now evidence to suggest that heading a football can leave younger players with lasting brain damage.[15] The US Soccer Federation has announced its intention to publish guidelines to limit the number of times children between the ages of 11 and 13 can take headers in training, and to ban them altogether for younger children.

Because children's heads are disproportionately large and their brains are not fully formed, there is more movement inside the skull. In addition to this, the brains of children and adolescents have not fully developed the protective myelin that covers neurons and, consequently, may be more vulnerable to head injuries.

The making of Vanessa-Mae

In 2008, a BBC programme called *The Making of Me* explored the nature/nurture debate through examining whether the famous violinist Vanessa-Mae's talent was a result of either her birth or her upbringing.

Vanessa-Mae learned the violin from the age of five and practised daily for four hours. She has sold more than 10 million albums and has performed on stage worldwide with many other renowned artists.

During the programme, Vanessa-Mae underwent a series of tests, including brain scans, heart monitoring and psychometric assessments. She discussed the main influences in her life with geneticists and a psychologist. Throughout these discussions, Vanessa-Mae expressed how she had inherited her talent from her mother. But, at the same time, she accepted that her mother's encouragement to play the violin was a significant influence in honing her musical talent from early childhood.

As Vanessa-Mae claimed during the programme:

'Kids can be born with potential but unless it's encouraged – pushed, even – I don't think it will ever come to fruition.'

The human brain continues to grow and develop throughout our lifespan. Its plasticity means that, whatever the genetic blueprint we are born with, our neural connections and structures are constantly changing to reflect our experiences, choices, environmental influences, even our thoughts and expectations.

Our brain is therefore a reflection of the world we have around us, for better or worse.

Top Tips
Remember: **BRAIN**

Balance your neurotransmitters in order to regulate your wellbeing and overall mood. Neurotransmitters are essential to our psychological and physical health. Chapter 12, Our Brain and Lifestyle, offers ideas for how to boost neurotransmitter balance through sleep, exercise and food.

Recognise, utilise and celebrate any male/female differences around you. Our evolution has depended on the appropriate dynamic between male and female characteristics. We all have something to offer and can complement each other well.

Activate your brain and challenge it regularly with mental exercises, memory games and new ideas. This will help keep your brain agile. A connected brain is a healthy brain, and if you do not use your brain, you will weaken its connections in those areas. The more you learn, the more connections you will create.

Invest time and effort in practising what you would like to become good at. Becoming an expert at any activity involves a great deal of dedication. There are no shortcuts!

Nourish your brain with the right environment and people around you. Make sure you are surrounded with people who believe in you and want the best for you. How you nurture your brain is as important as the brain you are born with. The influences you give your brain will affect changes to its structure and function throughout your lifetime.

References for Chapter 1

1. Joel, D. et al. (2015). 'Sex beyond the genitalia: The human brain mosaic', *Proceedings of the National Academy of Sciences,* October, 15468–73.
2. Rippon, G. (2019). *The Gendered Brain.* London: Bodley Head.
3. Nishizawa, S. et al. (1997). 'Differences between males and females in rates of serotonin synthesis in human brain', *Proceedings of the National Academy of Sciences*, May, 5308–5313, Karolinska Institutet (2008), 'Sex Differences In The Brain's Serotonin System', *ScienceDaily*, February 2008.
4. Brizendine, L. (2010). *The Female Brain*. London: Transworld Publishers.
5. Gao, S. et al. (2016). 'Oxytocin, the peptide that bonds the sexes also divides them', *Proceedings of the National Academy of Sciences*, June 7650–54.
6. Fillingim, R.B. et al. (2009). 'Sex, gender and pain: A review of recent clinical and experimental findings', *Journal of Pain,* May, 447–85.
7. Fladung, A., & Kiefe, M. (2016). 'Keep calm! Gender differences in mental rotation performance are modulated by habitual expressive suppression', *Psychological Research,* November, 985–96.
8. Pintzkaa, C.W. et al. (2016). 'Changes in spatial cognition and brain activity after a single dose of testosterone in healthy women', *Behavioural Brain Research,* February, 78–90.
9. Koscik, T. et al. (2009). 'Sex differences in parietal lobe morphology: Relationship to mental rotation performance', *Brain Cognition,* November, 451–59.
10. Ardekani, B.A. et al. (2012). 'Sexual dimorphism in the human corpus callosum: An MRI study using the OASIS brain database', *Cerebral Cortex,* August, 2514–20.
11. Verma, R. et al. (2013). 'Sex differences in the structural connectome of the human brain', *Proceedings of the National Academy of Sciences,* January, 823–28.
12. Blakemore, S-J. (2019). *Inventing Ourselves. The Secret World of the Teenage Brain.* London: Transworld Publishers.
13. Johnson, S.B., & Jones, V.C. (2011). 'Adolescent development and risk of injury: Using developmental science to improve interventions', *Injury Prevention,* February, 50–54.
14. Weiwei, M. et al. (2013). 'The corpus callosum of Albert Einstein's brain: Another clue to his high intelligence?' *Brain,* September, 1–8.
15. Di Virgilio, T.G. et al. (2016). 'Evidence for acute electrophysiological and cognitive changes following routine soccer heading', *EBioMedicine,* November, 66–71.