Why Icebergs Float

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It’s extraordinary to think that the brain, with all its thoughts and feelings, is driven by chemicals and electricity.’ Helen captured in a sentence what most members of the group had been silently thinking. Yes, it’s fascinating to hear about the latest MRI research and read about the various parts of the brain with their complicated Latin names, but at the fundamental level it’s really hard to imagine our mental experiences happening in this way. Neurons flashing on and off, endorphins flushing through the grey matter: it all seems disconnected from the everyday thoughts and dreams that occupy our minds. Of course people have different beliefs about the ultimate basis for our emotions and reasoning – but whatever these may be, an increasing body of facts about the workings of the brain are being uncovered by fast-moving scientific advances.

Individuals in the group had read various articles and books linked to the subject, and some had watched documentaries on television. More directly, issues of mental functioning and personal development had touched the lives of everyone in the group at some point, in one way or another. No-one had particular expertise in brain science, but all had reasons to be curious about it. As a consequence the group decided to settle on the subject for a few months, to pool their experiences and see how far a little reading and surfing would take them.

Pooling experience

Sally kicked off an exchange of experiences with the story of her niece who had suffered a brain tumour at the age of four. Surgeons had operated to remove it and a surprising consequence was that her personality had changed dramatically. From being a relatively shy child she became
overnight much more outgoing. Helen recalled a television programme in which damage to a person’s brain tissue had resulted in her becoming addicted to gambling. As Rosie observed, ‘it seems strange that an addictive tendency could be due to a part of the brain rather than some kind of external influence. You’d think gambling would take a hold because of the lure of financial gain or the influence of friends. I suppose it’s easier to imagine a chemical influence in the case of alcohol or drugs.’

Almost everyone round the table had experience of a friend or relative with a mental health problem, depression in particular. Sally and Patrick both knew people who had been treated with ECT (electroconvulsive therapy); it had fortunately proved beneficial in both cases. ‘But what is ECT exactly?’ asked Rosie. ‘It seems a bit brutal to simply shock the brain indiscriminately.’ She answered her own question shortly afterwards by consulting the Royal College of Psychiatrists website. Apparently the electric shock induces a kind of epileptic fit. It had been noticed that people with epilepsy seem to feel better after having a fit. It is not fully understood how this happens, but it is known that depression is associated with altered behaviour of certain chemicals in specific parts of the brain. It is thought that the epileptic fit may influence this for the better. Given the risk of side-effects, on memory for example, the treatment today tends to be restricted to severe cases for which other treatments have failed.

A malfunctioning brain seemed to be at the heart of other problems people had heard about. Alzheimer’s was affecting the elderly relatives of several people round the table. Julie’s mother, for example, had been gradually losing her memory. ‘It’s bizarre and unpredictable. She can write her name and her daughter’s, but not her granddaughter’s.’ Others mentioned the mental health of children and teenagers, focusing on autism as a condition that has become better known through the book *The Curious Incident of the Dog in the Night-time*. This is another example of a specific brain disorder about which awareness is increasing. It affects information processing by altering how nerve cells in the brain connect up, though the details of how this happens are not understood.

As discussion progressed, it became clear that the group was tending to focus on disorders of the brain. Mental health seems to be increasingly talked about today – a good thing and a marked improvement on the past. Perhaps it was the changing culture that was causing this: a decreasing sense of stigma, less covering up of conditions. Or was it the result of better treatments, or increased understanding brought about through the advent of new technologies such as the MRI scanner? Whatever the cause, everyone seems to be acquainted with the effects of
mental ill-health in one way or another. But, as Rosie pointed out at this point in the discussion, ‘Shouldn’t we also be looking at the brain from a positive point of view? After all, it is responsible for the way we think and feel in good times as well as bad!’ ‘Of course,’ others chimed in, ‘it’s the brain that does our thinking. It’s creative, imaginative and full of thoughts. It’s responsible for our feelings of happiness and joy as well. Where would we be without these?’

So how do we begin to discover more about how it all works? Perhaps one starting point is to map out something of the various branches of science that contribute to our understanding of the brain. After all, it’s not only brain surgeons who know something about the brain.

**Studying the brain**

An arcane subject just a few decades ago, with little written for the general public, brain science has become more widely recognised recently through the popularity of accessible books such as Oliver Sacks’ *The Man Who Mistook his Wife for a Hat*. Much of the evidence for the stories of people with extraordinary cognitive disorders came originally from neurosurgery – in particular from case histories of people who had suffered injuries to specific parts of the brain. Patrick had read about an example in which the tissue that connected the left and right halves of a person’s brain had been cut in an operation, pretty much a last resort intervention in a case of severe epilepsy. When a cup was placed in one of the patient’s hands he had no problem recognising it; when placed in the other hand, he could feel the object but not name it. This sad example provided important clues about specialisation in the separate halves of the brain. It is now understood that the right hemisphere is involved in spatial tasks and with emotions such as empathy, humour and depression, while the left is more dominant in verbal tasks such as speaking and writing and for scientific and mathematical skills. However, popular myths about left-brain and right-brain personalities are rejected by neuroscientists – now actively researching the complex ways in which the two halves interact and, to some extent, overlap with each other.

A quite different area of research about the brain is the field of experimental psychology. These studies are not aimed so much at explaining precise mechanisms of the brain, but at measuring what happens under varying experimental conditions. In this way properties of the brain can be inferred. An interesting example was raised by Patrick who had been reading the popular science book *How the Mind Works*
by Steven Pinker. A psychologist, Paul Ekman had researched whether facial expressions of emotion developed culturally as a baby grows up or were universal. It appears that many expressions, including anger, disgust and fear, are, to a large extent, the same in all cultures. Other branches of experimental psychology focus on our senses, the portals through which the external world impacts on the brain. Research into visual and aural perception, for example, reveals ways in which the brain interprets the world. The way we perceive certain images, for instance, has led to the concept of Gestalt: the idea of an overall form which the brain imposes on elements in a sensory field. The theory explains how the perceptual system forms a percept of the whole as a reality on its own, independent of the elements of which it is composed, as the following diagrams illustrate beautifully (Fig. 7.1). When you gaze at these figures, the apparent white triangle in (a), for example, is created in the brain; so is the sphere in (c).

Early studies of the brain focused, as you might expect, on its physical make-up, its anatomy. Studies of the structure of brains of the deceased enabled many distinct parts to be identified. Links between these structures and a number of functions were established by studying people who had suffered damage to specific regions. For example, the

![Fig. 7.1 Examples of the brain imposing form](image-url)
brain of an individual able to understand speech but not to talk was analysed *post mortem* by the French anatomist Paul Broca. He found damage in a particular area at the front of the brain. Such studies demonstrated what we now take for granted: distinct regions of the brain are associated with particular aspects of our functioning and behaviour. We now know, for example, that a region at the back is important in visual perception. The frontal region is associated with thinking and planning, among other things, and a deep region in the oldest part of the brain, in evolutionary terms, controls our breathing and heart rate.

This concept, known as localisation, has developed enormously with the advent of modern scanning technology. ‘Ah yes,’ Sarah chipped in eagerly at this point in a discussion. ‘My aunt had an MRI scan. What does this actually do? It’s a pretty noisy procedure, does it do any harm?’ MRI machines are relatively new devices that use magnetic properties of the atoms in your body. Unlike when you have an X-ray, no radiation is shone on to your body. Instead strong magnetic fields are applied; these affect the hydrogen atoms in the water of which much of your body is composed. This causes the atoms to emit electromagnetic signals that are picked up by the machine. The scanner is able to pinpoint exactly where the signals are coming from, enabling it to create a remarkably precise map of the body. See chapter 17 for more detail.

In brain studies this technique is applied in what is called functional MRI scanning to identify places where blood flow is increasing. This occurs wherever neurons are active, thus revealing areas of the brain that are functioning at any given moment. In this way the parts of the brain that are active under different circumstances – thinking, seeing or hearing, for example – can be identified. Through Sarah’s question another group of disciplines that contribute to modern neuroscience had been identified – the engineering and basic sciences that are developing the technology for neurologists and anatomists to use.

As the discussion group gradually became aware of the basic geography of the brain, a fundamental point became increasingly clear. The human brain was quite obviously not created, as it were, in one go; it evolved over time, as *Homo sapiens* itself evolved. It is not as though the ideal brain design just appeared. The brain we have today is an accumulation of older and younger parts, reflected in their physical locations and in the type of function for which they are responsible. Thus the oldest part, called the brain stem, is right at the bottom of the brain where it becomes the spinal cord. It plays a key role in fundamental functions: sleeping and eating, breathing and maintaining heartbeats. The most recent part, the large cerebral cortex, lies higher up on the top
of the brain and is associated with higher functions, including language and thinking. Interestingly all vertebrates share a common basic form, a three part system of hindbrain, midbrain and forebrain. The brains of mammals, one particular class of vertebrates, are distinguished by being generally much bigger, with a more developed cerebral cortex.

**How does it all work?**

The layout of the various parts of the human brain and the way in which they have evolved are central to the descriptions of the organ given in books and websites about human biology. However, these are rarely the starting point for people in discussion groups who want to know more about the subject. Their concerns are more related to how the brain affects our daily lives. ‘Isn’t memory bizarre?’ exclaimed Helen on one occasion. ‘You can forget the name of someone familiar to you, yet recall the exact details of some music or smell from years ago.’ ‘Yes,’ added Sally, ‘what is happening when you forget something and are reminded of it? Sometimes you recall it, other times you don’t.’ ‘And what about false memory – what on earth is going on in the brain there?’ asked Rosie, thinking of a recent legal case. ‘Does the brain contain the memory or not?’

Memory is indeed a popular area of discussion. Another is the social aspect of brain functioning – the effect of the early environment on infants’ brain development and the way in which the brain affects mood and behaviour through its interaction with hormones. In the remainder of this chapter we follow these matters of interest, but first a word or two about the physiology of how the brain works – the basic processes.

**Neurons**

The fundamental unit of the brain, and indeed of the whole nervous system, is the nerve cell or neuron. Its structure is outlined briefly in chapter 6. Here we look a little more closely at how it functions. A typical human brain contains an unimaginable number of these cells, approximately 86 billion. This huge number is comparable to the number of stars in the Milky Way galaxy, estimated at between 100 and 400 billion. Difficult though these numbers are to grasp, the really important figure for understanding brain capacity is not in fact the number of neurons, but the number of connections they make with each
other at junctions known as synapses: 100 trillion, roughly one thousand times the number of neurons. This tells us something important about brain functioning: each neuron must have many, many synapses – places where one neuron connects to another. It’s the degree of connectivity, not the number of ‘wires’, that really counts. So the brain is a kind of electrical signalling system in which each component is linked to up to 1,000 others. This is what distinguishes the brain – not its size nor the number of its cells, but their connectedness.

Synapses

Neurons are specialist cells, characterised by their unusual long, thin extensions (called axons) along which electrical pulses pass. The dimensions of these axons and their electrical properties are reminiscent of electrical wires, but, as indicated in chapter 6, electric pulses travel along them in a quite different way. Rather than the steady flow of electrical charge found in wire circuits, momentary pulses of rising and falling voltage pass along the membranes of nerve cells. They do this, when stimulated, by allowing electrically charged atoms (known as ions) to flow in and out of the membrane of the cell in a coordinated sequence, rather like the up and down movement of individuals in a Mexican wave (Fig. 7.2).

In this way an electrical pulse moves along the length of a long axon right to its tip. Linked to each of these axons are a number of connections to neighbouring nerve cells. It is at these junctions, the synapses, that the signal from one neuron is passed to the next. But this connection process is quite unlike the usual electrical procedure of linking two wires together, in which the charge flows continuously across from one site to the next. The biological equivalent is a more complicated process; it is central to the way we think and act, and is implicated in the onset of brain disorders such as Parkinson’s disease. At the junction between two neurons, the pulse travelling down the first one triggers off the release of a chemical substance, which passes out of the first neuron, travels across the tiny gap to the next neuron and passes through the membrane of the second neuron. Inside the second neuron this chemical, known as a neurotransmitter, initiates a new electrical pulse which, in effect, carries the signal forward. In this way a message is passed by relay from neuron to neuron, like the lighting of a chain of beacons (though somewhat faster!). Armed with this vivid image of messages travelling along nerve cells jumping from one to the next, thanks to the neurotransmitters, new questions naturally arose in the discussion group. ‘So are these
the chemicals in the brain people talk about?’ Helen asked. ‘Is this where dopamine comes in? Isn’t it involved in Parkinson’s disease?’

Yes, dopamine is indeed one of the neurotransmitters. Surprisingly there are quite a few different ones. You might have thought one chemical would be enough to link up different nerves, but evolution has left the human brain with many – dopamine, serotonin, acetylcholine, histamine, adrenalin, endorphin, to name but a few. In fact there are many different types of neuron mediating different functions in different parts of the brain. Different neurotransmitters are associated with each of these. ‘OK, so let’s take Parkinson’s disease as an example – what’s the role of dopamine?’ asked Rosie. ‘Isn’t it part of the treatment?’

The symptoms of Parkinson’s disease are caused by a decrease in the levels of dopamine, due to the death of the cells in the brain that

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**Fig. 7.2** A pulse moving along a nerve cell
make the substance. In recent years research in biochemistry, physiology and pharmacology has enabled drugs to be developed that mimic dopamine and thereby stimulate nerve cells. Though not the cure we all wish for, such drugs can help to alleviate symptoms. Developing treatments of this kind is an important motive for research in the basic as well as the applied sciences. Even though fundamental research of this kind is essentially exploratory – and therefore its outcome is unpredictable – understanding of basic structures and mechanisms is essential if treatments are to be developed.

One discussion group gained direct insight into this kind of research by arranging a visit to a researcher in a cell biology laboratory. Invited to peer down a microscope at a mass of tiny nematode worms, just a millimetre long and wriggling around full of life, the group heard these were essential to fundamental research into depression. Apparently, despite the relatively tiny size of the nematode’s nervous system, the mechanism of nerve transmission is similar to that of humans in important ways. The neurotransmitter serotonin is present in both, and the way in which it transmits signals can be explored more easily in the simpler species. Low levels of serotonin are associated with depression in humans and a comparable effect can be observed in nematodes: they stop wriggling about. This example illustrates how an area of fundamental research, in which a simple creature functions as a laboratory model, can play such a vital role in informing the subsequent development of drugs for human disorders.

In recent decades a very important discovery has been made about the way in which synapses, the junctions between nerve cells, are strengthened or weakened through experience. It turns out that each time a synapse is activated it not only transmits a signal to the next cell; it also consolidates its own existence. The more times a synapse gets used, the more secure is the connection it makes. This phenomenon, known as synaptic plasticity, has remarkable implications. Researchers are now beginning to develop a model of the biological mechanisms of memory and learning. We all know that learning necessarily involves a degree of practice and repetition; now we see there is a corresponding process of repetition at the cellular level. Networks of neurons become strengthened in the brain when the connections between neurons are repeatedly activated. In addition to the implications of this ‘plasticity’ for memory and learning, it also modifies our ideas of the brain’s capability. Far from being a fixture, as previously thought, we now know that brain capacity is capable of development throughout the course of life. This new understanding is already affecting the ways in which stroke
patients and others with nervous system disorders can be helped. It also adds to the case for adult education, reinforcing the concept of lifelong learning.

**Brain and hormones**

At this point discussion might well have deepened, to look into the mechanism of nerve transmission and its defects. After all, many important ills including addiction, autism and depression, are associated with defects at the synapse. As it happened, however, the conversation turned in a different direction altogether: to the link between the brain and hormones.

Stephanie, an experienced psychotherapist, took up the thread. ‘Some of the chemicals in the brain we have mentioned affect our moods, don’t they? Take adrenalin, for example: as far as I know it surges when you are in danger. Doesn’t it cause the “fight or flight” response?’ ‘Good point,’ agreed Helen. ‘I have often wondered: if the roof falls in, how do I know how to act? Would an animal know there was danger if the roof falls in?’ This point was taken up by Sally, who observed that if the roof collapses your brain picks up signals immediately through the visual and auditory senses – and presumably many kinds of animal would react in a similar way. Rosie added that learning must also be involved; ‘after all a child learns that fire is hot’. ‘Animals have built-in reactions as well as learned ones,’ she continued. ‘Think of birds; they use some kind of magnetic sense to navigate as they migrate, don’t they?’

A more philosophical note was introduced when Rosie raised the issue of the division of mind and body. ‘In Eastern philosophical traditions,’ she said, ‘they just aren’t treated as separate.’ ‘Isn’t it down to Descartes that we in the West think of the two as so disconnected?’ Helen responded. ‘It makes it difficult for us to reconcile experimental evidence about the brain with our personal experience of living.’ This latter point neatly captured an undercurrent running throughout the entire discussion. In effect an objective scientific view, based on emerging research and incomplete information, was being combined with subjective points of view based on people’s direct experience of life and love. With the traditional separation between mind and body, we are constantly busy trying to figure out what is a cause and what an effect. Did the adrenalin start coursing through my veins because of the fear? Or did its presence in my blood cause me to feel frightened? Which caused me to take that mood enhancing drug: me with my freely chosen desires or my neuron
circuits with their addictive response? ‘At least in some respects we are getting better at understanding this these days,’ commented Sally. ‘At least we have the concept of psychosomatic causes which is generally accepted. For instance, my GP told me that she is doing research on how the occurrence of accidents seems to be related to the levels of stress a person is experiencing.’ The relationship between hormones and the brain took hold of the group, and to investigate further the members decided to read around the subject. A particular feature was found that provided a closer look at how the two interact: the pituitary gland, buried deep at the base of the brain.

**The case of the pituitary gland**

The pituitary gland is a kind of super-gland located at the bottom of the brain. What first struck the discussion group was the extraordinary contrast between its size and its importance. ‘It’s amazing!’ Helen exclaimed. ‘How can such a small thing be so crucial to our hormone balance?’ The pituitary is often referred to as the ‘master gland’ because it controls several others – the adrenals and thyroid, for example – yet it is only the size of a pea. It sits in a bony hollow below the base of the brain, behind the bridge of the nose.

The great interest of the group, however, was less in the anatomical detail and more in how events in the brain affect our feelings – how nerves interact with hormones, in other words. How does a chemical affect our behaviour? What makes a child grow so rapidly? Why do children turn grumpy in their teens? What triggers animals to spawn and to migrate? A host of interesting questions followed, pointing to the link between the brain and the endocrine system – the complex system of hormones.

We have seen already how messages get relayed around the brain through complex networks of nerve cells, linked together in their billions. We’ve also seen that this biological network is not organised in quite the same way as a network of wires that you might find inside a computer, for example. As we saw, it’s not that electric current flows from one wire to other wires connected to it. Instead neurotransmitters are released which pass out of the cell and diffuse across the gap to the connected cell where they trigger off a new pulse. So much for a reminder of how the synapse works; now what about the pituitary gland? What happens here?

It seems that a somewhat similar process happens in the gland as in the nerve. But in this case it’s not that an electrical signal in one
nerve cell kicks off another one in the next cell; instead an electrical signal kicks off a chemical signal that goes on to affect the whole body. In effect electrical pulses from nerve cells in the brain cause hormone molecules to be released into the bloodstream. These hormones then spread all over the body, producing their various effects. The details of this process have been revealed by painstaking research in many disciplines over recent decades. It turns out that neurons in the brain are able to pass their electrical signals to a particular part of the brain called the hypothalamus, located at the base of the brain. In this specialised region the neurons (called ‘neurosecretory cells’) have a special property. At the far tip of their long axons these cells contain small packages which are filled up with hormone molecules. But these specialised neurons are not connected to further neurons, as in most parts of the brain. Instead they connect directly to the walls of a neighbouring blood vessel – a tiny capillary. By passing through the permeable walls of the capillary these hormone molecules are released into the bloodstream, ready to circulate freely throughout the body. ‘It’s as though this is the moment at which mind meets body,’ said Jean, thrilled by the idea of a link between electrical signals flashing through the brain and hormones flowing in the blood.

The hormone exerts its effects in a two-stage process that seems unnecessarily complicated at first sight. The job of this hormone is to stimulate further types of hormone which then circulate around the body. In this two-stage process the original stimulating hormone released from the nerve cell goes on to release a variety of other important hormones. These include growth hormone, puberty hormones (gonadotrophins) and ACTH, a hormone which itself goes on to stimulate yet another hormone, cortisol, strongly associated with stress. In each case the action takes place well away from the pituitary, in whichever part of the body is appropriate – the kidneys or gonads, for example. But, as Anna suggested, even though there are a limited number of types of hormone it’s reasonable to expect a wide range of different effects. As she put it, ‘cake recipes only involve a few ingredients, but there are endless variations in what you can make with them.’

Stephanie, the psychotherapist in the group, found this insight into how the brain influences our emotions particularly interesting. In her professional life she deals with children and young adults living with exceptionally high levels of stress. In her understanding it was quite possible for trauma experiences early in infancy, especially if repeated, to set the stress response at the wrong level; this can go on to affect responses in adult life. This observation chimed with a common feature
of hormone systems. Their job is often not just to set a process in motion, such as lactation or bone growth, but also to regulate it, so that it operates at the right level, neither too much nor too little. In this respect hormone systems are analogous to a thermostat which regulates the temperature of a room by taking action if it falls too far or the opposite action if it rises too high. Regulating body temperature is an example of this, and ensuring the right level of sugar in the blood is another.

**Conclusion**

These insights into the nature and role of hormones inevitably throw up new questions. As you might imagine, the discussion group was not slow to pose a stream of them. What do hormones look like? Are they all the same kind of thing? Where do they come from? If they are just messengers how do they produce their effects? How do they know when to switch on for puberty and pregnancy? Most fundamental of all: what exactly is a hormone? Eager as the group was to pursue these questions, a detectable glazing of their eyes spoke clearly: there’s only so much you can take in at a single sitting. The hidden world of hormones became the subject for many further months of discussion and as a consequence, forms the basis of the next chapter.

Before moving on to this intriguing subject, however, let’s reflect briefly on the many ideas about the brain presented in this chapter. We’ve seen how research in many disciplines – surgery, anatomy, physiology and psychology, for example, to say nothing of physics, computer science and philosophy – has combined to give us our present insights. From the nineteenth century concept of phrenology to contemporary images derived from magnetic resonance technology, the geography of the brain has provided vital knowledge. So too have detailed studies of the structure of individual nerve cells and the chemistry and physics of their operation. We’ve explored the all-important synapses, the junctions between nerve cells, and the networks they give rise to. Finally, in a move to connect our ‘thinking’ brains with our ‘feeling’ bodies, we have seen how nerve cells are able to unleash hormones into the bloodstream, producing the extraordinary changes we all experience as we grow older and grapple with the complexities of life.

The next issue to tackle is how the firing of cells up in the brain can give rise to physical and emotional changes throughout the rest of the body. How does a stimulus from the eye or a long-stored memory
set the heartbeat racing or unleash a sense of joy? One particularly important process for this involves the complex system of hormones. Linked as they are with feelings of wellbeing or sadness, and with profound changes affecting our bodies at crucial stages of life, hormones figure prominently in group discussions. What follows is an account of several such discussions and some of the research that accompanied them.