THE MIND OF A GENIUS

PICKLED BRAIN, ANYONE?

Cogito ergo sum. "I think, therefore I am." This quote from the French philosopher René Descartes is a perfect way to open any book about the brain. Our brains enable us to think and to remember. To feel a fragrant breeze caress our cheek. Our brains make us want to investigate the world. Perhaps your brain made you pick up this book? Whether you finish it or not, you can thank your brain for deciphering the black squiggles on this page and, hopefully, finding meaning in the words. And not to forget: Brains enable us to produce thoughts that can change the world forever.

For thousands of years, marvellous ideas and exceptional works of art have been ascribed to 'divine inspiration', but how do they arise in the brain of a genius? We do not know. When Albert Einstein died in 1955, an American pathologist named Thomas Harvey removed the eminent physicist's brain before his body was cremated. Harvey, believing Einstein's brain could explain his phenomenal ingenuity, photographed the organ, cut it into 240 pieces and made wafer-thin slices of brain tissue to study the cells under his microscope. He was sorely disappointed.

The brain of an adult male *Homo sapiens* typically weighs 1350 grams (about three pounds). To Harvey's surprise, Einstein's brain weighed just 1230 grams, so for brains (as for various other organs) size is not decisive for success. This is also good news for females of our species, whose brains are, on average, 10% smaller than male brains – like Einstein's was.

Harvey failed to find the key to Einstein's genius under the microscope, and the tissue that once hosted a brilliant mind was gradually forgotten in a cardboard box in Harvey's office. Fortunately, the large pickling jar holding Einstein's brain tissue resurfaced, and today select slices are on display at museums around the world.

Researchers are still studying Einstein's brain, but we now know that the links between brain structure, thoughts and behaviours are far more complex than Harvey could ever have imagined. The quest goes on as scientists search for the genesis of excellent ideas like theories of relativity, Facebook and pre-sliced bread.

SLICED PORRIDGE

Harvey's idea that the secret of Einstein's genius could be found in the microscopic structures in his brain had its roots in the late 1800s. An Italian physician named Camillo Golgi believed mental illness could result from brain damage, so he began to study slices of brain tissue from deceased patients to prove his theory.

But Golgi had a problem. Under a microscope, slices of brain basically look like flattened blobs of cold oat porridge, so he had to develop a method to highlight the tissue structures that might expose the mysterious workings of the mind.

In 1873, many experiments later, Golgi developed a chemical reaction that could dye or 'stain' the constituent parts of brain tissue in different shades. His process was remarkable – almost like developing an image in a darkroom and watching it materialise on photographic paper. Suddenly, Golgi's microscope revealed an extensive network of branching fibres that had characteristic patterns in different parts of the brain.

Golgi drew everything he saw under his microscope, creating veritable works of art. News of his staining technique and of the brain's complex structures quickly spread. Like many of his contemporaries, Golgi believed the nerve fibres were parts of a single, vast, unified cell.

One exception was the Spanish physician Santiago Ramón y Cajal. After seeing Golgi's drawings in 1887 and applying his technique, Ramón y Cajal realised the brain actually consists of billions of tiny individual cells. The treelike structures Golgi had described were extensions of the nerve cells we now call *neurons*.

Ramón y Cajal was also the first to discover the neuron's many *synapses* – tiny, toadstool-shaped projections on the neuron extensions that enable neurons to communicate by releasing chemical messenger molecules – *neurotransmitters*. A neuron looks a bit like a tree. Picture its lower trunk and root end – the *axon* – acting as a conduit that sends signals down into a network of extensions tipped in synapses, which are in contact with other neurons. The thick upper trunk of this tree, containing the neuron's cell nucleus, spreads into a crown of delicate branches – *dendrites* – which receive signals from the synapses of other neurons.

In 1894, Ramón y Cajal proposed that the brain stores information in the networks neurons create through their synapses, and not, as one might think, by generating new neurons for new information. His description of neurons heralded the birth of modern neuroscience.

300,000,000,000,000 CONNECTIONS

Today, we know a human brain contains about 85 billion neurons. Each of these communicates, on average, with 7,000 other neurons, which each in turn communicate with another 7,000 neurons, and so on and so forth.

By comparison, estimates say that each of Earth's roughly 7.5 billion inhabitants has a social network of 300–700 people. Put simply, it would be far more complex to understand how a brain's network operates than to map out the communication between everyone alive on the planet today – a huge challenge even for the combined resources of all the intelligence and security agencies in the world.

Now let's take a look at your brain. You have probably seen a 'pudding-bowl haircut', the kind that looks as if you simply put a pot on someone's head and cut away everything below the edge. Do *not* try this at home, but imagine that instead of scissors we took a saw and cut through the skin and the 5–10 mm of bone in your cranium. Removing the domed lid, we could bare your greyish *cerebrum*, which takes up most of the space in your skull cavity. It is covered by protective membranes, which we could gradually remove, revealing the blood vessels on its uneven surface.

The cerebrum consists of two nearly symmetrical halves, each roughly the shape and size of half a cantaloupe melon sliced lengthwise. The two halves are covered by the grey-toned cerebral *cortex*, whose *grey matter* contains the neurons' cellular nuclei and countless dendrites. The cortex is 1–4 mm thick and folds in upon itself, creating a convoluted landscape of half-inch-wide *gyri*, each ridge or *gyrus* separated from the others by deep grooves or *sulci*.

Beneath the cerebral cortex, the long neuronal axons form the brain's *white matter*, which is a profusion of biological wires enabling the various parts of the brain to communicate. These wires also carry your brain's commands to your muscles and internal organs, and they receive sensory input from your skin, eyes, ears, nose and mouth.

The wires are white because of *myelin*, a fatty substance that insulates the axons. Thanks to myelin, your neurons can send electrical impulses racing across long distances at over 200 kilometres (125 miles) per hour.

Besides its 85 billion or so neurons, your grey matter contains an equal number of star-shaped cells called *astrocytes*. Their myriad extensions connect with the brain's blood vessels and neuronal synapses. Certain parts of

Einstein's brain seem to be unusually rich in astrocytes, and scientists are still trying to understand what these enigmatic cells do – and whether they help us get bright ideas.

NEURAL PATHWAYS SWITCHING SIDES

Each half of your cerebrum is divided into *lobes*. Starting above each eye socket, the *frontal lobe* stretches from your forehead back to the *central sulcus*, a deep fissure that separates the frontal lobe from the *parietal lobe*. The central sulcus begins at the apex of the skull, slanting downwards to a point about midway between the outer corner of your eye and your outer ear canal.

Neurosurgeons quickly learn to recognise the central sulcus. They are acutely aware that damaging the gyrus in front of the central sulcus – that is, the gyrus at the rear of the frontal lobe – can cause permanent paralysis in a patient. Brain researchers call this area the *motor strip*, because you use the cortex here to perform movements, such as turning the pages of this book.

A blood clot or tumour that damages the motor strip on one side of the brain will paralyse parts of the opposite side of the body. This is because the neural pathways switch sides on their way from your cerebral cortex to your muscles. The cortex on the parietal lobe just behind the central sulcus is called the *sensory strip*. A kiss on the cheek or a stone in your shoe puts this area to work, and once again the sensory apparatus on the left half of your body sends signals to the right half of your brain, and vice versa.

Behind your eye sockets, beneath your frontal lobes,