

1 DEFUNCT MYTHS

The consensus used to be that the earth is flat. Combustible materials, eminent scientists once proposed, all contain the nonexistent substance phlogiston. Mars, they told us, is crisscrossed with canals. All these once-influential ideas have been consigned to the scrap heap of obsolete theories. Brain science too has its share of defunct notions. This chapter is about those brain myths that no one (or very few people) believes any more. We'll start with the ancient idea that the mind is located, not in the brain, but in the heart. As the importance of the brain was eventually accepted, other myths to emerge or persist were that the nerves are filled with animal spirits and the main mental functions are located in the fluid-filled hollows of the brain: the ventricles.

Myth #1

Thought Resides in the Heart

It seems obvious to us today that thoughts and reason are located in the brain. That's because we've grown up knowing this universally accepted fact. But from a subjective point of view, there's little, other than the position of our eyes, to tell us that our mental life is housed in our heads. So perhaps we shouldn't be too surprised that many ancient civilizations from the Greeks to the Egyptians believed that the seat of mental function was located not in the brain but in the heart.

It is not that these cultures were necessarily unaware of the functional significance of the brain. Extracts from the Edwin Smith Surgical Papyrus (bought by the American archaeologist Edwin Smith in Luxor in 1862

and dated to approximately the age of the Pyramids) show us that the Ancient Egyptians recognized the potential effects of brain injury, including paralysis. But despite this knowledge, the cardiocentric view persisted, and the brain was seen as little more than a kind of bone marrow (today, the word for brain in many languages, including Russian “мозг,” Maori “roro,” Indonesian “benak,” Persian “مغ,” and Swahili “ubongo” means literally “marrow”). Ancient Egyptian practices regarding the burial of the dead are revealing. Although the heart and other organs were venerated after death, left in the body for burial or preserved in canopic jars, the brain was scooped out via the nostrils, or a hole drilled in the base of the skull, and simply discarded.

In Ancient Greece, the Homeric poems from the eighth century BC reveal a belief in there being three types of soul – the psyche (a life-soul that animates the body), the thymos (associated with emotions), and the noos (associated with reason and intellect). The noos and thymos were both located in the chest, although not specifically in the heart. Among the first scholars to identify the heart specifically as involved in thought was Empedocles of Acragas (circa 495–435 BC) who believed that blood around the heart produced thoughts.

Perhaps the best-known cardiocentric advocate was Aristotle (384–322 BC). Like many others he was swayed by the fact that life ended when the heart stopped beating. Aristotle also noted how the brain was cold, senseless and peripheral whereas the heart was warm and central; that the heart develops in embryos before the brain; and that it is connected to all the sense organs whereas the brain is not (or so he mistakenly thought). Aristotle further reasoned that the brain couldn’t be the control center for movement and sensation because invertebrates don’t have brains.¹

Although he didn’t see the brain as the seat of thought, Aristotle saw it as an important organ – he believed it was a bloodless, cooling radiator for the heart and that it was also involved in sleep. Another notable cardiocentrist was the physician Diocles of Carystus (circa fourth century BC) who made great breakthroughs in heart anatomy. Unfortunately, he interpreted his discoveries in line with his belief in the heart as a cognitive center, and so he saw the ear-like auricles of the heart as sense organs. Madness, he believed, is caused by the blood boiling in the heart (echoes of this idea remain today, as in “you make my blood boil”), and melancholy by the thickening of black bile, also in the heart.²

The cardiocentric view had actually been challenged decades before Aristotle by the philosopher-physician Alcmaeon of Croton (circa 450 BC), and later by Hippocrates, the “Father of medicine” (born circa 460 BC),

and his followers. Alcmaeon was among the first scientists to perform animal dissections. Although his writings have been lost, quotations by others tell us that he wrote: “The seat of sensations is in the brain ... it [is] also the seat of thought.” In a paper published in 2007, the neurobiologist Robert Doty at the University of Rochester argued that Alcmaeon’s revelation was so profound as to be comparable in historical significance to the discoveries of Copernicus and Darwin.³

Also long before Aristotle, the Hippocratic treatise *On The Sacred Disease* (circa 425 BC) states: “Men ought to know that from the brain and the brain only, arise our pleasures, joys, laughter and jests, as well as our sorrows, pains, griefs and tears” and it goes on to attribute thinking and perceiving to the brain too. Another prescient Hippocratic treatise, *On Injuries of the Head*, states correctly that damage to one side of the brain causes impairments to the opposite side of the body.

After Hippocrates, further important breakthroughs were achieved by the Alexandrian anatomists, who were the first to perform systematic human dissections. Active around 300 BC, Herophilus of Chalcedon, often considered the founder of human anatomy, studied some of the cranial nerves and the ventricles (the fluid-filled hollows in the brain), while Erasistratus of Ceos compared the human cerebellum (the cauliflower-shaped “little brain” that hangs off the back of the brain) with the equivalent structure found in animals, deducing correctly that it must have something to do with movement. Both Herophilus and Erasistratus identified correctly the existence of separate sensory and motor (involved in movement) nerves in the human brain and spine.⁴

But as we’ve seen, long after the case for the brain (the encephalocentric view) was put forward, belief in cardiocentrism refused to go away. In the third century BC, all Stoic philosophers continued to believe that the intellect and soul reside in the heart. A particularly influential advocate at this time was the Stoic Chrysippus of Soli (277–204 BC). Among his arguments was that the mind must reside in the heart because the heart is the source of the voice, which is controlled by thought. Indeed, one of the reasons the cardiocentric view was so difficult to overturn was that many of its advocates were convinced by this kind of specious logic. They also believed the cardiocentric view must be true because it had been adhered to for so long and by so many great thinkers and poets. Incidentally, claiming that a fact must be true because it is endorsed by one or more authority figures is a hallmark of poor argument that is still used to today by those advocating pseudoscientific positions.

In the second century AD, frustrated by the continuing influence of Chrysippus and contemporary members of the cardiocentric camp, Galen

“the Prince of physicians” famed for his treatment of gladiators at Pergamon, decided to perform a dramatic public demonstration in which he severed the recurrent laryngeal nerve of a pig.⁵ Cutting this nerve, which travels from the brain to the larynx (voice box), had the effect of stopping the animal from squealing as it continued to thrash about. Following the logic espoused by the cardiocentric advocates, severing nerves that originated in the brain should not have stopped the pig from squealing, unless the cardio view was wrong and speech and thought were controlled by the brain, as Galen argued. Galen’s demonstration undermined their claims in what the historian Charles Gross describes as the first experimental demonstration of the brain’s control of behavior.

Unsurprisingly perhaps, not everyone was convinced. Galen was heckled by, among others, the philosopher Alexander Damascenus, who said the demonstration only applied to animals. In fact, belief in the mental function of the heart persisted in many quarters all the way through to the Renaissance. Consider the writings of William Harvey, the English physician celebrated for his description of the circulation of the blood round the body. His classic work, *De motu cordis et sanguinis in animalibus* (published in 1628), describes the heart as the highest authority, ruling over the rest of the body. There are still hangovers from this myth to this day, in the way we allude to the psychological function of the heart in expressions like “to learn by heart,” and when we imply the heart is the seat of love.

It is important to add a note here that while cognitive function is based principally in the brain, there is growing evidence that the function of the heart certainly affects our thoughts and emotions (see pp. 163 and 166) so we ought not to be too dismissive of the cardiocentric views held by the Ancients.

Myth #2

The Brain Pumps Animal Spirits Round the Body

Some of the discoveries made by Galen and the Alexandrian anatomists seem remarkably modern. But their prescience can be misleading. The world at that time in fact knew virtually nothing about the biological brain processes that support mental function, and this remained the case for centuries to come.

For instance, despite his ground-breaking anatomical work, Galen, like most others of his time and beyond, was a strong believer that the body contains two different kinds of spirits. He thought inhaled air was transformed into “vital spirits” in the heart, and that these were converted into

“animal spirits” or “pneumata psychikon” when they reached the brain. This conversion process he thought took place in the brain’s hollow cavities (the ventricles) and in the *rete mirabile* (meaning “wonderful net”) – an intricate network of blood vessels he’d discovered in the base of the brain of several animals. In fact this network isn’t found in the human brain but Galen didn’t know this because he only dissected animals. Movement and sensation, Galen further theorized, are made possible by animal spirits traveling up and down the hollow nerves of the body, pumped by the brain.

The idea that animal spirits pulse through body sounds ridiculous to us today, but it was another idea, like the cardiocentric view of mental function, that showed remarkable longevity, only being debunked in the seventeenth century. One reason for its persistence was its vagueness. No one ever spelled out exactly what animal spirits are supposed to be, other than that you can’t see them or feel them because they’re weightless and invisible. This meant the theory could not be falsified using the technologies of the time. Today scientists recognize that any respectable theory should be logically falsifiable. That is, it ought to be possible to imagine the kinds of evidence that would indicate the theory is wrong, even if such evidence does not exist.

Another reason for the staying power of animal spirits was the centuries-long reverence shown by generations of scientists and medics to Galen’s writings. To challenge the great man was seen as sacrilege, partly because he’d managed to get so much correct, and partly because his mono-theistic religious beliefs were acceptable to Christianity and Islam, including his faith in the creative genius and power of God.⁶ A long-running ban by the church on human dissection through the Middle Ages also slowed down advances in neuroanatomy.

Even if we fast forward to the “father of modern philosophy,” René Descartes, who lived in the seventeenth century, we find that he still endorsed the idea of animal spirits – “a very fine wind,” he called them, “or rather a very pure and lively flame.” In fact these elusive entities were central to his influential ideas about the human soul and how it interacts with the physical body. Descartes located the soul in the brain’s pineal gland (a small structure at the base of the brain) partly because he thought the structure was perfectly placed to purify the spirits and keep track of their movements. We know today that the pineal gland is located above the ventricles and is a hormone-releasing structure involved in regulating daily and seasonal cycles. Descartes thought it was located in the ventricles and that its ability to rock and tilt allowed it to direct the flow of spirits through the brain. When we sleep,

Descartes reasoned, the brain goes slack because of the lack of spirits in the nerves; by contrast when we're awake, the spirit-filled brain is taut and responsive.

Even as Descartes continued to beat the drum for animal spirits, some of his contemporaries were at last beginning to challenge the idea. The specific mystery they were trying to solve, and for which spirits had for so long been seen as the answer, was “How does the brain interact with the body?” “How are signals sent down the nerves?” The evidence had been mounting against spirits. One scientist noticed that flexing his arm in a tub of water failed to displace the water, as he thought it should if spirits had flowed into his arm. Rival theories to emerge in the seventeenth century suggested that the nerves are filled instead with fluids or that they operate via the vibration of ether within them. The former idea, espoused by the English physician and neuroanatomist Thomas Willis, was soon defeated by basic observations – for example, no fluid comes out when you cut a nerve. The vibrations idea put forward by Newton also failed to gain much momentum – to begin with, the nerves aren't pulled taut as you'd expect if they worked in the way that he suggested.⁷

The discoveries that finally killed off belief in animal spirits had to do with electricity. Scientists had known about electric fish since at least Galen's time (when they'd been used as a headache treatment), but it was only in the eighteenth century that “electrotherapy” really took off, with numerous claims that electricity could be used to cure paralysis. This led scientists to ponder whether electricity could be the mysterious means by which the nerves communicate with each other and the muscles of the body. Among the pioneers who developed this idea was the Italian anatomist Luigi Galvani, who conducted a series of important experiments with frogs.⁸

A key revelatory finding came about by chance when an assistant was using a scalpel on a frog. The assistant was standing near one of Galvani's electrical machines that generated static electricity from friction. At just the moment that the machine threw out a spark, the assistant happened to be touching his scalpel against a nerve that innervated the muscle of the frog's leg. The leg suddenly twitched. This observation was crucial because it suggested to Galvani that the spark must have somehow acted on electricity that was already present in the frog nerve.

Galvani's nephew Giovanni Aldini went further. In grisly work he reportedly collected severed heads from the guillotine and showed how applying electricity to the brain caused the faces to twitch.

He performed his most theatrical demonstration of this effect in London in 1803, on the corpse of George Forster, shortly after Forster had been hanged for the murder of his wife and child.

Galvani later showed that nerves contain fat, which supported his correct belief that they often have a fatty coating of insulation that speeds up the transmission of electricity along their length. Incidentally, in 1850, the speed of human nerve conduction was established by the German medic and physicist Hermann von Helmholtz to be 35 meters per second. The serious neurological condition multiple sclerosis, first described by French neurologists in the nineteenth century, is caused by a degeneration of this fatty insulation around the nerves, leading their signals to become scrambled.

Myth **Brain Cells Join Together Forming** **#3 a Huge Nerve Net**

As any neuroscience student will tell you, electricity isn't the complete answer as to how nerves communicate. Yes, a current is passed along a nerve (today nerve cells are called neurons, a term first coined by Wilhelm Waldeyer in 1891), but this ultimately triggers the release of chemicals – neurotransmitters – stored at the end of that neuron. These chemicals then make contact with the receiving neuron, which is located on the other side of a tiny gap known as the “synapse” (a term proposed by Charles Sherrington in 1897 before there was definitive evidence that such gaps existed). When these neurotransmitters act on the receiving neuron, they make it more or less likely that it too will experience a burst of electricity along its length.

However, it wasn't until the end of the nineteenth century and into the twentieth that we reached this level of understanding about how the messenger cells of the nervous system communicate. To reach that stage of knowledge required advances in microscope technology and in staining techniques that made it possible for the first time to see the structure of neurons in detail. A key character in this field was the Italian anatomist Camillo Golgi (known as the “savant of Pavia”), who developed a new silver stain technique in 1873. However, even his methods remained crude by modern standards. Golgi and his contemporaries couldn't see the gaps between neurons and they proposed that the cells of the nervous system are fused together, forming an elaborate nerve net – an erroneous idea known as the “reticular theory.”

Among the first scientists to propose tentatively but correctly that there might be gaps between neurons were Wilhelm His and August Forel in the late 1880s. However, it was the Spanish neuroscientist Santiago Ramón y Cajal who really killed off the nerve net idea thanks to significant improvements he made to Golgi's staining technique. Although his technology still wasn't advanced enough to show the gaps (the synapses) between neurons, Cajal's superior images also provided no evidence that neurons are fused together. Based on his findings, Cajal argued convincingly that neurons are distinct elements, separate from each other – what became known as the “neurone doctrine.” Cajal also proposed correctly that information flows in one direction along neurons.

Cajal and Golgi were jointly awarded the Nobel Prize in Physiology or Medicine in 1906 for their contributions to our understanding of brain anatomy. Here we find more evidence of the stubbornness of some old, incorrect ideas. Golgi used his winner's speech to espouse his original, outmoded ideas about nerve nets and, in rather unsporting fashion, he described Cajal's neurone doctrine as little more than a fad.

Myth #4

Mental Function Resides in the Brain's Hollows

Before moving on to mythical neuroscience practices in the next chapter, let's rewind once more to deal with another long-defunct theory that was closely related to the idea of animal spirits. We know today that the ventricles are filled with cerebrospinal fluid, acting as a shock absorption system for the brain. However, for centuries it was thought that the ventricles were filled with animal spirits and that each one subserved a different kind of mental function (see Plate 7).

The ventricular theory has its roots in ancient writings in the West and East but was only forged into a comprehensive theory in medieval times. This theory stated that perception is located in the anterior ventricles, cognition in the middle ventricle, and memory in the posterior ventricle, near the cerebellum. Perhaps the first full account of this theory was put forward around the end of the fourth century AD by the physician Nemesius, the Bishop of Emesa in Syria. However, many versions of the theory were proposed through history and around the world, each varying in the exact way that functions were allocated to the different ventricles.

The historian Christopher Green in his 2003 paper “Where Did the Ventricular Location of Mental Faculties Come From?”⁹ says that Nemesius was virtually unknown in his time and that his account was

unlikely to have influenced later scholars. Green reckons instead that St Augustine was more influential, at least in the West, in spreading the theory, via his work “The Literal Meaning of Genesis” written in AD 401. In this text he describes three ventricles:

One of these, which is in the front near the face, is the one from which all sensation comes; the second, which is in the back of the brain near the neck, is the one from which all motion comes; the third, which is between the first two, is where the medical writers place the seat of memory.

Centuries later, Leonardo da Vinci, whose anatomical discoveries were so astounding, was another advocate. Early in the sixteenth century, he injected hot wax into the brain of an ox to create a cast of the ventricular hollows, thus allowing him to depict the structures in greater detail than ever before. He labeled their functions according to Nemesius’s ancient scheme.

The “ventricular localization of functions” idea remained influential until Victorian times but was first challenged by a Renaissance anatomist from Belgium, Andreas Vesalius. In his landmark book *De humani corporis fabrica* (*On the Workings of the Human Body*), published in 1543, Vesalius showed from his dissections of human cadavers that people don’t have any ventricular cavities that aren’t shared by other mammals, thus undermining the idea that they are the source of distinctly human mental functions. However, he conceded that based on anatomy alone he couldn’t explain how mental functions are supported by the brain.

The ventricular theory was rejected in more compelling fashion in the seventeenth century by Thomas Willis, the author of the magisterial *Anatomy of the Brain*, which features illustrations by Christopher Wren. Drawing on evidence from patients with acquired brain damage and others with congenital brain abnormalities, as well from his own dissections, Willis made a convincing (and correct) case that many functions like memory and volition are located in the outer layers of convoluted brain tissue – the cerebral cortex – that are so much more developed in humans than in other animals. He roundly dismissed the possibility that such functions could reside in the brain’s “vacuities,” as he called them. Willis also discerned accurately that the stripy, kidney-shaped corpus striatum (located under the hemispheres) was involved in motor control (control over movements).

Despite Willis’s arguments and his eminence, the scientific dogma right through into the eighteenth century continued to see the cerebral cortex as no more than a rind (the literal meaning of the Latin word *cortex*), packed

full of blood vessels but little else. It wasn't until the rise of phrenology under Franz Joseph Gall in the nineteenth century that the functional importance of the cortex was more fully appreciated (see p. 28).

Notes

- 1 Finger, S. (2005). *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. Oxford University Press.
- 2 Crivellato, E., & Ribatti, D. (2007). Soul, mind, brain: Greek philosophy and the birth of neuroscience. *Brain Research Bulletin*, 71(4), 327–336.
- 3 Doty, R. W. (2007). Alkmaion's discovery that brain creates mind: A revolution in human knowledge comparable to that of Copernicus and of Darwin. *Neuroscience*, 147(3), 561–568.
- 4 Finger, S. (2005). *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. Oxford University Press.
- 5 Gross, C. G. (2009). *A Hole in the Head: More Tales in the History of Neuroscience*. The MIT Press.
- 6 Finger, S. (2005). *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. Oxford University Press.
- 7 Finger, S. (2005). *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. Oxford University Press.
- 8 Glynn, I. (1999). *An Anatomy of Thought: The Origin and Machinery of the Mind*. Oxford University Press.
- 9 Green, C. D. (2003). Where did the ventricular localization of mental faculties come from? *Journal of the History of the Behavioral Sciences*, 39(2), 131–142.