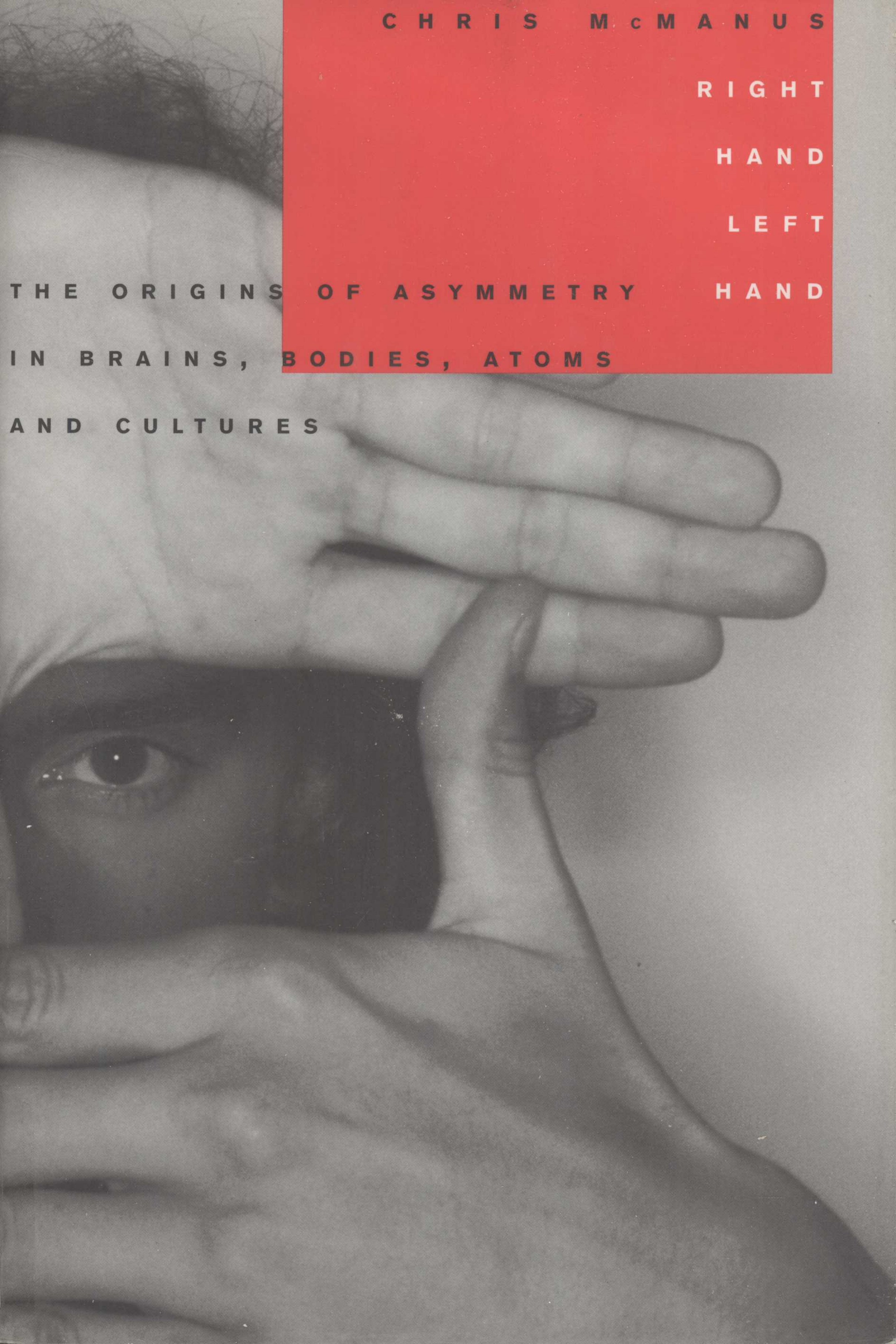
CHRIS McMANUS

RIGHT HAND LEFT HAND

THE ORIGINS OF ASYMMETRY IN BRAINS, BODIES, ATOMS AND CULTURES



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DR WATSON'S PROBLEM

John Reid was forty-eight in October 1835, when he died in the Middlesex Hospital in the centre of London. We know little about John Reid in life, except that he appears to have had no problems with his chest, no-one having bothered to examine it very thoroughly; which, as it happened, was unfortunate. Reid had been looked after by a dynamic young physician, Dr Thomas Watson, who wanted to know why his patient had died. A post-mortem was carried out, probably by Watson himself. No-one expected what was found – John Reid's heart was on the wrong side. Unlike the vast majority of people, who have their heart on the left, John Reid had his heart on the right side. Indeed, everything else was back to front as well. His liver was on the left rather than the right, and his stomach and spleen were on the right rather than the left. As Watson put it, the organs 'exacted the appearance which the same viscera... would present if seen reflected [in] a plane mirror' (see Figure 1.1). Watson described the condition then as heterotaxy, but the more usual name in modern scientific literature is *situs inversus*, meaning an inverted site or location for each of the organs.[1]

Dr Watson (Figure 1.2) had a keen, enquiring mind, and an obvious desire to reach the top of the medical profession, which he not only achieved, but managed while still remaining beloved of his peers; a difficult task in a competitive, self-critical profession like medicine. Born in 1792, he only started studying medicine at the age of twenty-seven, previously studying mathematics at Cambridge where he had been tenth wrangler. By 1835, he was a Censor of the College of Physicians. In 1842, his wife died of puerperal sepsis ('childbed fever'), and that same year he was the first to suggest that infection might be prevented by disinfecting the hands or by using what we now call disposable surgical gloves. In 1859, he was appointed Physician to the Queen, and in 1861 was one of the three doctors looking after Prince Albert when the prince died of typhoid fever.

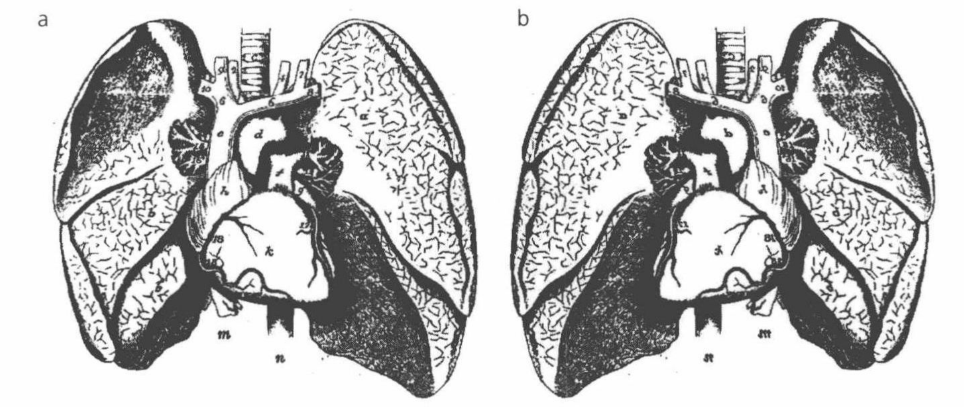

Figure 1.1 a, The normal layout of the organs of the chest (*situs solitus*) with the heart pointing towards the left, the arch of the aorta leaving the heart and looping over towards the left-hand side, the right lung having three lobes, and the left lung having two lobes. **b,** The layout of the organs of the chest in *situs inversus*, in which the pattern is a mirror-image of the case in *situs solitus* (in this case literally, the original engraving having been reversed or, as Watson put it, 'reflected in a plane mirror').

In 1862 he was elected President of the College of Physicians, a post he held for five years, and in 1866 he was created a baronet, having his portrait painted by George Richmond, the eminent society painter. Watson's entry in *Munk's Roll,* the historical record of the Fellows of the College of Physicians, describes him as 'the Nestor of English Physicians', a reference to the King of Pylos in Ancient Greece, who was the oldest and wisest of the chieftains who had gone to the siege of Troy. T. H. Huxley described him simply as 'the very type of a philosophical physician'.[2]

On 30 May 1836, Watson presented his findings on John Reid to an evening meeting of the College of Physicians. Sitting on the table was Reid's heart, which had been preserved in a bottle and was kept in the pathological museum of King's College, London. Later that year, Watson wrote a long account of Reid, along with a description of several dozen other cases, in an article for the *London Medical Gazette.* It was a *tour de force,* citing cases published in English, French and Latin, including a doggerel verse in French (written by Leibniz, the co-inventor with Newton of the calculus), and a quotation in Greek from Galen, the Roman physician who was second only to Hippocrates in the ancient medical world, and deemed an authority for a millennium and a half. Watson had canvassed opinions from several other eminent doctors in London, and had received a detailed history of a similar case from Sir Astley Cooper, one of the most distinguished and intellectual of London surgeons. Watson quoted verbatim from Cooper's description of this case, which concerned a woman called Susan Wright.[3]

We know somewhat more about Susan Wright than about John Reid. She was seventy-three when, on 19 March 1836, ten weeks before the meeting at the College of Physicians, she had died of an attack of diarrhoea. Her health previously had been generally good, and she was well known in the hospital, acting as an attendant on the wards, where it was commented on how adroit she was at dressing the patients' wounds and ulcers. We are told of her kindness and humanity, and that 'her habits were extremely temperate, although she had been on a few occasions observed in a state of inebriation'. She never married, 'and the appearances after death shewed that she had died a maiden, as the hymen still remained...'. The post-mortem was carried out by a Mr Braine, a surgeon of St James's Square, who opened the abdomen and found, to his surprise, that the intestines were completely reversed. The chest was then opened, found also to be completely reversed, and word was sent to Cooper, who examined the body the next day. As he then puts it, 'The viscera were removed with care...and sent to my house, where, having injected them, I had them dried and preserved.' These specimens were also on the table at the meeting of the College of Physicians.

In his article in the *London Medical Gazette*, Watson reflects on how one should describe these strange anatomical findings. He considers 'malformation' and 'monstrosity', and rejects each – there is no malformation, since there is nothing faulty or malformed about these organs, each being merely back to front; and likewise he rejects monstrosity since there is 'nothing constructed amiss, nothing wanting, nothing superabundant; therefore nothing monstrous. Every part and every organ is as perfect as in the ordinary fashion.' There is the rub, as Watson recognised. There is no obvious reason why the 'ordinary fashion' should be precisely that, ordinary, whereas the mirror image is extremely rare. Watson could see no difference in function between the two types: 'We are not sensible of any advantage, or comfort, from having the heart on the sinister and the liver on the dexter side; and therefore we cannot expect that any embarrassment or uneasiness should arise when that arrangement happens to be reversed.'

Watson struggled to make sense of the predilection of one side over the other when it would seem either way around would do equally well. He was aware that there is a biological dimension, and talked of how in most molluscs the spiral of the shell twists from left to right, while in a few individuals, or even whole species in some cases, the shells curl in the opposite direction. He played briefly with the idea that reversed viscera do not occur in animals, but was told by a student from King's College that Galen mentions it, and by a butcher that the phenomenon is sometimes found in sheep. This made him wonder if *situs inversus* in humans a

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Figure 1.2 Sir Thomas Watson **a,** An etching of 1854, by F. Hall after a drawing by Richmond. **b,** A photograph in 1867.

is perhaps actually not as rare as it seems, but merely difficult to diagnose in life.

To a modern medical eye the surprising thing is that most of these cases were not diagnosed in life, but only on opening the body at post-mortem. However, we must remember that the French physician Laënnec had invented the stethoscope only sixteen years earlier, in 1819, and that its use was still difficult, leaving room for error. We know that Watson himself certainly didn't like using the stethoscope, describing it many years later as 'more of a hindrance than a help', and saying that although 'he could not do without it... he did without it as much as he could'. Watson was not a Dr Lydgate, the thrusting young physician in George Eliot's novel *Middlemarch*, who believed fervently in science in medical practice, and who, in 1829, just a decade after Laënnec's discovery, when he examined the ageing Dr Casaubon, 'not only used his stethoscope (which had still not become a matter of course in practice at that time), but sat quietly and watched him'. Even so, Watson surely had no need of a stethoscope to make the diagnosis. One of the first things that all medical students learn is to find by touch the 'apex beat', the thrusting tip of the heart, usually located at the level of the fifth rib, on the left side, on the vertical line running down through the middle of the collar bone, the clavicle. It is not hard to find, and I have certainly seen cases of *situs inversus* where even from the end of the bed the apex beat is visibly palpitating on the right-hand side. At the end of his paper, Watson had to admit that, even in life, 'by carefully repeated examinations, no reasonable doubt could remain'. Perhaps, like Eliot's Lydgate, Watson should just have sat quietly and watched John Reid.[4]

If the mere existence of these unusual individuals with their mirror-image anatomy was a problem for Watson, there was another more troublesome issue lurking, one to which Watson devoted a large amount of his discussion. Even if John Reid and Susan Wright were complete mirror images of the normal situation, that would be difficult to explain. Harder still was the fact that not everything had been reversed in these individuals. Humans have several asymmetries, including that of the hands, most people being right-handed. *And John Reid and Susan Wright were right-handed.* Astley Cooper is specific in his description of Susan Wright that 'all who had observed her agreed, that she gave the preference to the use of the right hand'. These two cases cannot be written off as statistical flukes, since Watson reviews all the cases of *situs inversus* that he could find in the medical literature, and, while there is no evidence that any were left-handed, several others were indubitably right-handed.[5]

Watson was justifiably surprised that John Reid and Susan Wright were right-handed. Most people assume that individuals with *situs inversus* will be left-handed. The novelist H. G. Wells was no exception. In his science fiction tale, *The Plattner Story*, Gottfried Plattner manages to get blown up by a mysterious green powder, and disappears. On his return,

> the right lobe of his liver is on the left side, the left on his right; while his lungs, too, are similarly contraposed. What is still more singular, unless Gottfried is a consummate actor we must believe that his right hand has become his left... Since this occurrence he has found the utmost difficulty in writing except from right to left across the paper with his left hand.

Watson's counter-intuitive conclusion, that individuals with *situs inversus* are usually right-handed, has been amply confirmed by modern studies. In the most comprehensive of these, published in 1950 as a spin-off from mass X-ray screening examining for tuberculosis, Johan Torgersen, a Norwegian physician, described how 122 people with *situs inversus* had been found amongst 998,862 people examined using miniature radiographs, about one in ten thousand of the population. Torgersen also knew about another seventy cases. Although he did not know the handedness in all cases, of the 160 in which he did, only eleven (6.9 per cent) were left-handed, a proportion similar to that found in people with their heart on the normal side, the left.[6]

Perhaps the fact that John Reid and Susan Wright were right-handed was not so much of a problem as it seemed at first sight. After all, right-handedness is only a behaviour, and many behaviours are learned. We would hardly be surprised to find that John Reid and Susan Wright wrote from left to right, since that was what everyone else in Britain had learned to do. Maybe handedness is also a cultural convention, most people writing and carrying out other skilled tasks with the right hand because of what Watson called 'the mere force of custom or prejudice'. Watson tried to argue such a case, but he eventually dismissed it, coming down on the side 'that the dextral tendency is implanted by nature' (or, to put it in more modern terms, it is biological, and hence probably genetic in origin). He does though hedge his bets a little, adding the caveat that the tendency 'cannot be very strong, since, in spite of the aid of training, it is so often overcome by slight external influences' – and here he is probably on weaker ground, overcoming innate handedness being surprisingly difficult.

Watson's basis for concluding that right-handedness was biological in origin lay in cross-cultural studies. If right-handedness were indeed an arbitrary cultural convention in an otherwise symmetric world, then half of all societies should be right-handed and half left-handed. Watson's description of the evidence is clear and forceful:

> The employment of the right hand in preference to the left hand is universal throughout all nations and countries. I believe no people or tribe of left-handed persons has ever been known to exist... Among the isolated tribes of North America which have the most recently become known to the civilised world, no exception to the general rule has been met with. Captain Back has informed me that the wandering families of the Esquimaux, whom he encountered in his several expeditions towards the North Pole, all threw their spears with the right hand, and grasped their bows with the left.[7]

There is no modern evidence to refute Watson, and plenty to support it.

But Watson now had himself on the horns of a dilemma; one that he was completely unable to resolve and, indeed, that continues to be one of the most fascinating questions for modern research. If right-handedness is biological in origin, then how can people with *situs inversus*, with everything else in their bodies reversed, not also have their handedness reversed?

The mystery, though, was to deepen, becoming, in the words used by Sir Winston Churchill to describe the Soviet Union, 'a riddle wrapped in a mystery inside an enigma'. The riddle and the enigma of lateralisation were still to come. The riddle involved simple molecules, and the enigma

Figure 1.3 Louis Pasteur in 1852, four years after he had described the two types of tartaric acid crystal.

was neurological, concerning that ultimate cultural achievement, language. Both were discovered in France, within a decade or two of Watson's presentation at the College of Physicians; the first by Louis Pasteur and the second by Dr Marc Dax. We will look at them only briefly here, but return to them in greater detail in later chapters.

Louis Pasteur (Figure 1.3) was perhaps the greatest of French scientists. On 22 May 1848, at the age of twenty-five, he presented a remarkable paper to the Paris Academy of Sciences. While looking at the mechanism by which wine goes sour, he had compared the natural tartaric acid produced from grapes with racemic acid, which is produced industrially. He found that, although chemically identical to tartaric acid, racemic acid differs in its effect on polarised light. When dissolved in water, the natural tartaric acid rotates the polarised light clockwise, whereas the synthetic racemic acid has no effect at all on the polarised light. Looking down the microscope, Pasteur saw that the natural tartaric acid consisted entirely of one type of crystal, whereas the tiny crystals of racemic acid were a mixture of two types, one the mirror-image of the other. He is said to have shouted, '*Tout est trouvé!*', perhaps best translated as 'Eureka!' Pasteur then conducted a tedious but crucial experiment, using a microscope and dissecting needle to sort the crystals of racemic acid into their two types (see Figure 1.4). A solution of one type rotated polarised light clockwise, just like natural tartaric acid, whereas the other rotated it anticlockwise. A mixture of the two had no effect on light, each balancing out the other, as in racemic acid. An even more dramatic result was to come ten years later. Micro-organisms, Pasteur discovered, could survive and breed on the racemic acid which turned light clockwise, but could not metabolise the racemic acid that turned the light anticlockwise.[8]

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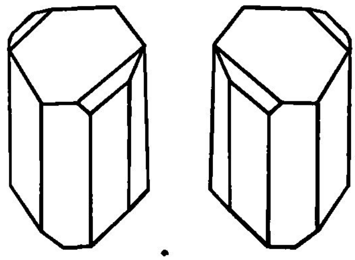

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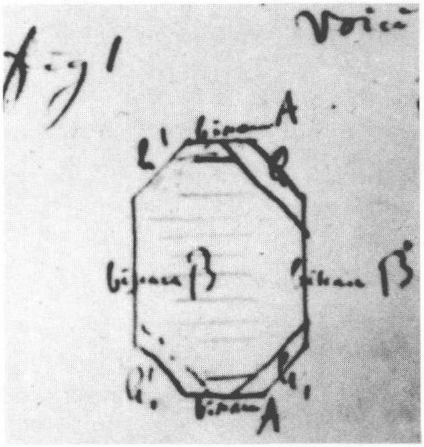

Figure 1.4 a, The crystals of racemic acid that Pasteur would have seen under his microscope. Natural tartaric acid from wine showed only the dextro or (+) form (left-hand figure).
b, Pasteur's own drawing of one of the two types of crystal.

Pasteur's finding revolutionised biochemistry. Very many of the molecules that comprise the body occur in the laboratory in two forms, one of which is the mirror-image (the stereo-isomer) of the other. But although two forms *can* occur, in the human body only one form of each molecule occurs. For sugars it is what we now call the D- (or dextral) form (from the Latin for right), and for amino-acids it is the L- (or laevo) form (from the Latin for left), according to whether they rotate polarised light to the right or left. This total dominance of one type over the other is not unique to humans, but applies to almost every living organism found on our planet (with occasional intriguing exceptions that we will come back to in chapter 6).

What would have been the implications for Watson twelve years earlier if he had known about this? They would have been profound. Watson had assumed that the basic building blocks, the bricks from which the body is built, are symmetric, for there was no reason to believe otherwise. However, when a house, a machine, a body or whatever is built out of asymmetric bricks, then building a mirror-image is very much more difficult. Look at Figure 1.5. This is a simple spiral staircase built from stone steps that are symmetric. If the stones are merely turned over, then the staircase will turn in the opposite direction. One set of components will build either a right- or left-hand staircase. Now look at the staircase in Figure 1.6. Each stone step is asymmetric. When these steps are stacked on one another they make a right-handed staircase. Imagine, though, trying to use these same stones to build a left-handed staircase. It is simply not possible. The asymmetry of the components determines the asymmetry of the structures built with them.[9]

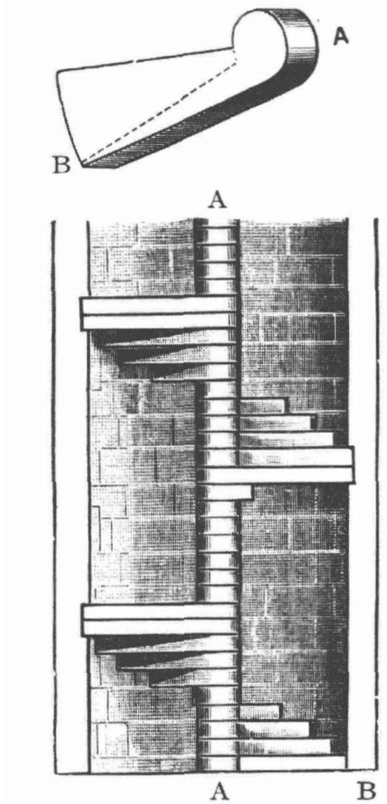

Figure 1.5 Building a simple spiral staircase. The top picture shows an individual step of which the staircase is built. It is symmetric, so that a staircase built from it (lower picture) can spiral in one direction (shown here), or in the opposite direction.

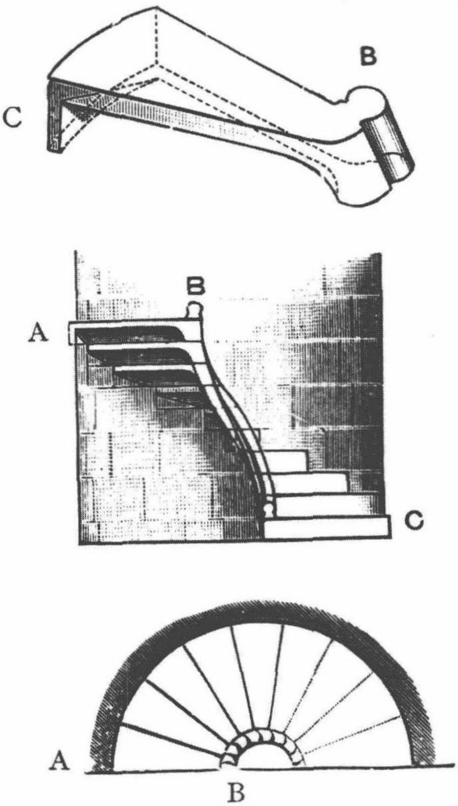

Figure 1.6 Building a complex spiral staircase. The top picture shows the individual step of which the staircase is built. Note that it is completely asymmetric, coming in left- and right-hand forms, of which only one is shown here. The result is that the staircase, shown in the middle and lower parts, can only spiral in one direction.

If the body is composed entirely of one set of stereo-isomeric molecules, does that explain why we almost all have our heart on the left? Maybe. However, if so, the greater difficulty remains in explaining how it is possible to build a body *at all* with the heart on the right, and also in determining whether we can any longer regard individuals with *situs inversus* as being mere mirror-images; individuals who just happen to be one way round rather than another. It is as if we had tried to print something to be looked at in a mirror but had used only normal letters such as 'a', 'b', 'c' and 'd', which are asymmetric. Here, then, is the first of Watson's additional problems – he'd claimed that '*a priori*, we can perceive no reason why the viscera should be disposed in the one way rather than in the other'. Well, now there was indeed a reason, a very strong reason, even if the route from molecule to viscera was extremely obscure.

If Pasteur's discovery was the riddle, then the enigma, which was to provide so much difficulty for Watson, had in fact manifested itself only a few weeks after his presentation at the College of Physicians, although neither he nor anyone else took note of it for a quarter of a century. Just as the experiments of that obscure monk, Gregor Mendel, were ignored for decades until the time was ripe for understanding them, so the work of Dr Marc Dax was equally ignored. Dax, who was born in 1770, spent most of his life, from 1800 until his death, practising medicine in Sommières, a small town twenty miles north-west of Montpellier in southern France. Dax is now remembered for a paper he presented in July 1836 at a medical conference in Montpellier, *Le Congrès Méridional*. Loosely translated, the paper's title was 'Damage to the left half of the brain associated with forgetting the signs of thought [that is, a loss of words]'. The paper was read aloud but never printed, and Dax himself died the next year, at the age of sixty-six, his ideas all but disappearing into oblivion. However, nearly thirty years later, in 1865, his son, Dr Gustave Dax, published the manuscript of his father's paper, the topic of language localisation having become one of the hottest in scientific Paris, as a result of the claim made by Dr Paul Broca that language was located in just one half of the seemingly symmetric human brain.[10]

Dax senior's 1836 paper begins with an incident from September 1800, when he saw a patient, a captain in the cavalry, who had been wounded in the head by a sabre blow and had difficulty in remembering words. Dax had been reading the work of Gall, the phrenologist, who believed that different mental functions were located in different parts of the brain. Dax therefore asked where the cavalry officer had been wounded, and was told the left parietal region (that is, on the side of the head). Gall had never suggested that mental functions could be located on only *one* side of the brain, and hence the whole story was mystifying. However, over the years Dax saw more and more patients and eventually concluded that, despite it making little sense in Gall's typology, loss of language was associated with damage to the *left* half of the brain.

Dax junior published his father's manuscript because of an extremely acrimonious and lively debate taking place in the Académie de Médecine, the Société d'Anthropologie and the Société Anatomique in Paris. This started originally as a debate on the location of language in the brain, with Jean-Baptiste Bouillaud claiming that language was located in the frontal lobes, just above the orbit of the eye. In 1861, Paul Broca (Figure 1.7), a surgeon with wide-ranging interests in anatomy and anthropology, saw two patients both of whom had problems with language.

Figure 1.7 Dr Paul Broca, photographed in his fifties, a decade or so after he had described the brains of Tan and Lélong.

Remarkably, we have photographs of the brains of these two patients, both having been preserved in Paris. The first patient was called Leborgne, but had long been nicknamed *Tan* from the single spoken word that he could produce. He had been an epileptic since childhood, initially being paralysed in the right arm and then, later, in the right leg. He had been institutionalised at the Bicêtre Hospital for the previous twenty-one years. His death came suddenly at 11.00 am on 17 April 1861, from a neglected cellulitis and gangrene of the right leg. Twenty-four hours later, a post-mortem was carried out, the brain being removed and, within a few hours, displayed at the Société d'Anthropologie, after which it was preserved in alcohol. It can be seen in Figure 1.8, where, somewhat unusually, the brain has been preserved in a vertical position. If the page is rotated ninety degrees anti-clockwise the view is more conventional. The precise cause of Tan's illness is still unclear, but what is obvious, even from the relatively poor-quality photograph, is that a large area of damage is present in the left frontal lobe. That the damage was so localised was what principally interested Broca, particularly when, a little later, a second patient showed almost precisely the same damage.[11]

The name of the second patient was Lélong. In the spring of 1860, as an eighty-three-year-old man, he collapsed with a stroke, after which his daughter reported he was unable to speak. Eighteen months later, on 27 October 1861, he fell over and fractured the neck of the left femur. In the era before hip-replacement surgery, a broken hip was effectively a death sentence, and twelve days later Lélong died, under the care of Broca, to whose surgical ward he had been admitted. The post-mortem

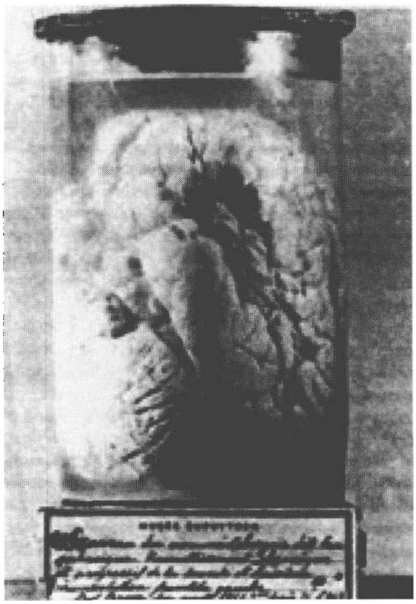

Figure 1.8 The brain of Leborgne (Tan), preserved in the Musée Dupuytren. The brain is stored vertically, with the frontal lobes at the top and the cerebellum visible in the lower left-hand corner. Only the left cerebral hemisphere can be seen in this photograph. The large, dark, horseshoe-shaped area in the middle, about a third of the way down the image, is the damage in Broca's area.

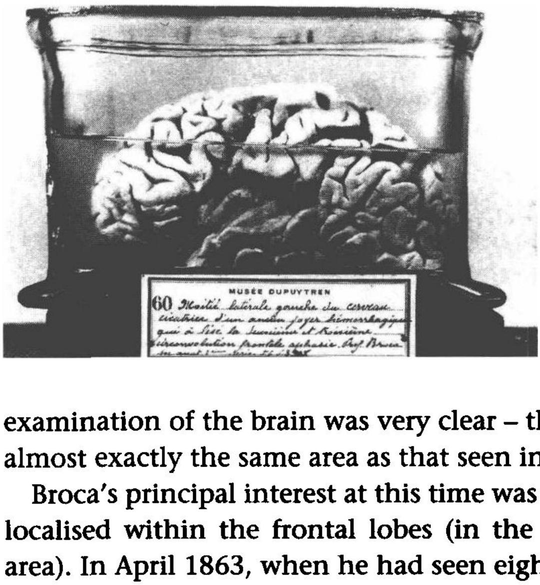

Figure 1.9 The brain of Lélong, preserved in the Musée Dupuytren. The left cerebral hemisphere can be seen. Unlike the brain of Tan in the figure above, this is stored in a more conventional position, with the frontal lobes to the left and the cerebellum not visible (it would be beneath the cerebral hemispheres on the right side of the picture). There is a large area of damage visible just above the left-hand half of the label.

examination of the brain was very clear – there was an area of damage in almost exactly the same area as that seen in Leborgne (Figure 1.9).

Broca's principal interest at this time was that the areas of damage were localised within the frontal lobes (in the place now known as Broca's area). In April 1863, when he had seen eight patients, all with damage in the left hemisphere, he commented that it was 'remarkable how in all these patients the lesion was on the left side. I do not dare to draw any conclusion from this and am waiting for new data.' Later in the same year, he would describe no less than twenty-five further patients with what he called aphemia (but soon became known as aphasia); that is, a loss of language. All the patients had left-sided brain damage. These patients were all diagnosed when alive, the side of brain damage being known because each had a hemiplegia, or paralysis, of the right side of their body. One of the strange features of the nervous system is that the right side of the brain controls the left side of the body and vice versa, the fibres from brain to body 'crossing over' in the brain stem. This meant that Broca's patients with a right-sided paralysis had damage to the left half of their brain.

For Broca the implications were clear:

> From the physiological point of view this is a most serious matter ... [I]f it were shown that one particular and perfectly well determined faculty ... can be affected only by a lesion in the left hemisphere, it would necessarily follow that the two halves of the brain do not have the same attributes – quite a revolution in the physiology of nervous centres. I must say that I could not easily resign myself to accept such a subversive consequence.

Broca was absolutely right – it would indeed be subversive and was, in fact, 'quite a revolution'. How could two seemingly identical masses of grey matter of the brain be so different? One, the left, was responsible for language – that highest faculty of the human mind and the jewel in the crown of civilised life – and the other, almost identical in form, permitted just a few monosyllabic grunts of the sort made by Tan and Lélong. Yet, so it is. The basic finding has not been disputed since the time of Broca, everyday experience of any practising physician or neurologist repeatedly confirming it.[12]

One of those practising physicians was Thomas Watson himself. In 1871, at the age of seventy-nine, he published the fifth edition of his *Lectures on the Principles and Practice of Physic,* one of the most successful medical textbooks in Victorian England, the first edition of which had been published nearly forty years earlier in 1843, based on his lectures at King's College, London. Watson was honest enough about the ease of replicating the basic finding: 'On looking back on brief notes, kept through many years, I find frequent evidences of the conjunction of some form of aphasia with right hemiplegia.' Watson had even published such cases; for instance, in the first edition of his textbook. Despite such cases, Watson was still sceptical about Broca's theory that language resided in specific parts of the brain: 'I cannot accept – I put no faith in – the theory upheld by M. Broca.' He cited an opinion which he attributes to Dr John Hughlings Jackson, the great London neurologist, then at the height of his powers, that 'the faculty of language resides nowhere in the brain, because it resides everywhere'. The problem with that, though, is clear – if language is everywhere, how can it be that damage to the left cerebral hemisphere results in aphasia, whereas damage to the right hemisphere typically does not? Watson struggled for some sort of theoretical model, much as he had done thirty-five years earlier, and he returned to an old interest – handedness.[13]

Since it is clear the brain itself is visibly symmetric, then the highly asymmetric association of aphasia with right hemiplegia seemed unlikely to come from the brain itself. Instead, Watson pointed out that our two eyes, lungs and kidneys all behave from birth as a pair, each responsible for half of normal functioning. The two halves of the brain, he argued, would also do the same were it not for 'one notorious exception. We all grow up right-handed.' According to Watson, the result is that the brain is educated for language on one side only, the left side. Language lateralisation on the left therefore follows on from, and is directly caused by, right-handedness. Watson moderated this statement a few sentences later, noting that 'the right side may indeed sometimes appropriate [language], just as some few persons are left-handed'. Here, at least, is some sort of explanation of why not everyone has left-sided language. But the theoretical mess was about to get deeper, for Watson was still trying to make sense of why we are mostly right-handed (which he again claimed to be universal – 'common ... to all nations and races').[14]

Now Watson came up with an entirely different theory; one that is utterly but interestingly flawed. He returned to the anatomy of the body and looked at the blood supply to the brain. The arteries in the chest leading from the heart are as asymmetric as the heart itself, which means that the carotid arteries providing the main blood supply to the cerebral hemispheres are also asymmetric (Figure 1.1).

> Owing to the well-known arrangement of the arteries which rise from the aortic arch, the left hemisphere receives by the carotid a more direct and therefore freer supply of blood than does the right. Probably from this cause ... the convolutions of the anterior lobe of the left hemisphere [that is, Broca's area] are developed at an earlier period than those of the opposite side ... In this same fact we find a probable reason for most men being right-handed.

On first impressions it looks like a good theory, but a few moments of reflection reveal that it cannot possibly be correct. Watson's own observations of 1836 undermine the argument, for if we are right-handed and have left-sided language because of the asymmetry of the blood supply to the brain, then individuals with *situs inversus* should mostly be *left-handed.* Watson himself, however, had emphatically shown that they are not.[15]

Sir Thomas Watson has helped us map out the ground we are going to explore. The problems he highlighted are as acute today as when he first raised them, and there are others related to these that are also equally problematic. There are, then, exciting times ahead. Definite progress has been made in recent years, much of it in the past two decades. Since the early 1960s, there have been huge amounts of research into handedness and the difference between the cerebral hemispheres. At a more anatomical level, biologists in the 1980s, after years of almost totally ignoring the question, realised that there are interesting and profound problems in understanding how and why vertebrates have their heart on the left side. Again, great progress has been made. In the process, there has also been much study of the relationship between anatomical asymmetries and biochemical asymmetries – the big question being whether they are directly related in any causal sense. The answer is probably yes, as we shall see.

In 1991, the Ciba Foundation realised that real advances were being made in understanding why biological organisms were asymmetric, and it organised a meeting entitled 'Biological Asymmetry and Handedness'. For three days, twenty-nine scientists – from physicists, chemists and biochemists, through anatomists, development biologists and palaeontologists to psychologists and neuroscientists – discussed and debated these issues. All of those disciplines were needed, as it was increasingly realised that full understanding of any one involves all the others. The meeting was chaired by Lewis Wolpert, himself a left-hander, who, as an experimental scientist, couldn't resist starting the meeting by testing a pet hypothesis of his own: that left-handers would be over-represented among the participants. They were not – two participants were left-handed, representing seven per cent; a proportion comparable with the general population and with laterality researchers in general. At the end of one wonderfully varied but heavy discussion session, Lewis commented light-heartedly, 'From molecules to brains in one easy session!' It had indeed spanned that range, although 'easy' would probably not be most people's description. Here we will try to link those areas, looking for evidence from a very wide range of disciplines, although it will not always be easy. It should, however, take us into many of the nooks and crannies of the physical, biological, cognitive and social worlds.[16]

In studying handedness in all its forms, we will traverse scales from the very smallest to the very largest, from the sub-atomic to the cosmological. Although we will find that there seem to be asymmetries, or forms of handedness, at each of those levels, we will also find that much of their meaning and importance comes from a universal human desire to treat left and right as symbolically different. That, therefore, is where this book starts.

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DEATH AND THE RIGHT HAND

The death was as pointless as so many others in the First World War. It took place twenty miles east of where, a year later, 650,000 French and German soldiers would die in the 'mincing machine' of the battle for Verdun which A. J. P. Taylor described simply as 'the most senseless episode in a war not distinguished for sense anywhere'. At 2.50 on the afternoon of 13 April 1915, a spring day with perfect weather conditions, a French lieutenant leading the men under his command climbed out of his trench, walked ten metres towards the enemy and fell, mortally wounded. His two sub-lieutenants followed and, in their turn, fell almost immediately. They had covered no more then a dozen steps of the three hundred yards of open country separating them from the enemy lines, when, in clear view, they were mown down by the German machine guns. A few moments later twenty-two soldiers lay dead. One of the sub-lieutenants killed was Robert Hertz (Figure 2.1), a sociologist and anthropologist, who was just thirty-three years old when he died. His body, lying side by side with the other two officers, was recovered the following night. Hertz's last letter to his wife, Alice, showed his sense of foreboding prior to that day, finishing, '*un baiser grave et pieux – pour toujours*' (a solemn, devoted kiss – for ever).

The attack on the village of Marchéville that Hertz had been part of was unlikely ever to have been successful – the officers were well aware that they were walking to almost certain death. It was described later by Hertz's friend, colleague and posthumous editor, the sociologist Marcel Mauss, as '*l'attaque inutile*' (the useless attack). The military objective was undoubtedly important. The plain of the Woevre, which led directly to the German fortress town of Metz, was bisected by the River Meuse, and in September 1914 the German army had gained a rapid tactical advantage by establishing a bridgehead across the river at St Mihiel. The battle of the Woevre, in which Hertz took part, failed to regain St Mihiel, this