Carl Zimmer
Soul Made Flesh: The Discovery of the Brain - and How It Changed the World
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"Gentlemen, instead of promising to satisfy your curiosity regarding the anatomy of the brain, I here confess, sincerely and publicly, that I know nothing about it." The scientist who pronounced these words went on nevertheless to deliver a learned talk, in which he recounted in detail dissections of the brain that proved why the great Mr. Descartes had not understood its anatomy. The year was 1664, or 1665. The place was Melchidésec Thevenot's academy in Paris, one of the salons where natural philosophers, amateur experimenters, anatomists and men of letters gathered until Colbert, in 1666, instituted the Académie des Sciences, following the model of the Royal Society across the Chanel. The speaker was a Dane called Nicolaus Steno, or Niels Steensen, now remembered chiefly for his prescient work on fossils and for the treatise on the brain in which the foregoing words were recorded (eventually he gave up science, converted to Catholicism in Italy, and became a bishop).

Over three hundred years have elapsed since then, and in no previous century has it been possible to study the brain as we are able to now. New techniques of brain mapping, new fields of study and new ways of merging them - immunology with developmental neuroscience, cognitive psychology with information theory, and so on - are yielding an increasing amount of data about the mind or what, for millenia, was called the soul. Studies abound on memory and emotion, antisocial behavior and religious frenzy, the ability to calculate, recognize faces or find the way home, the biological basis for altruism, selfishness and even moral judgement.

Yet Steno's words are still pertinent, because the more details we learn about the brain, the more complex it appears - and the more puzzling appears the relation between the brain we are unravelling bit by bit, and the self-conscious mind. A map of the brain may well reveal something about how the mind works, but our mental life seems much greater than the sum of cerebral parts. This "mind-body problem" has as long a history as the anatomical science that Steno tackled until he turned to the full-time practice of faith, and has steadily accompanied atttempts, from the Presocratics on, to place the soul somewhere in the body.

Carl Zimmer's vibrant account of these efforts does not include Steno but dates the birth of what he calls our "Neurocentric Age" to the physician and anatomist Thomas Willis, an English contemporary and admirer of the Dane, celebrated in his lifetime, buried with pomp in Westminster Abbey, but, by the time of the Enlightenment, largely forgotten. Today, he remains familiar merely to specialists such as historians of science, although his last name is enshrined in the brain itself as the Circle of Willis, the arteries at its base and that supply its blood - first seen, and understood, by the man who coined the term "Neurologie" to describe his new "doctrine of the Nerves".

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The neurosciences clearly are still in their infancy, but the field is evolving so fast that twenty-year old research is already considered ancient by now. Their relevant history

begins at the earliest in the 19th century, during the course of which scientists such as Paul Broca helped establish the notion that all mental functions were localized in specific areas of the brain; the neuron began to be understood, thanks to the work of Rámon y Cajal and others; and it finally became acceptable, with Darwin, to conceive of the brain as an evolved organ, continuous with the nervous systems of the planet's other species, from crayfish and sea-horses to cows and primates.

In Zimmer's view, however, Willis is the field's true pioneer, and his work, starting with the *Anatomy of the Brain and Nerves*, or *Cerebri Anatome* in the first, Latin edition published in 1664, was its forerunner, three hundred and forty years ago. Its author was a man who "did for the brain and nerves what William Harvey had done for the heart and blood: made them a subject of modern scientific study" - and arguably, one might add, what Philippe Pinel would do for psychiatry one hundred years later. The very notion of a neuroscience, specifically, rests on the principle that, in order to study the human mind - sensation, emotion, cognition, intentional action, and so on - one must study the brain and nervous system. Willis emerges in this book as the first researcher ever to conduct a systematic study of the brain on the basis of that principle: as a Galileo of the soul, a key contributor to the new order of thought set in motion during the intellectually ebullient, politically tumultuous period of crisis and revolution that was the seventeenth century, and the creator of a new set of assumptions about the mind that we today take for granted but whose origins are inextricably linked to that period.

Zimmer recounts how Willis dissected human brains and studied them afresh and anew, discarding in a number of magisterial strokes ancient theories about the structure of the human soul that were still mainstream in his time. From his humble beginnings in the Oxford of the 1640s as a country doctor and "Pisse-Prophet" who dabbled in alchemy and in experiments based on William Harvey's novel, revolutionary theory of the circulation of the blood via the heart, he had become by the time of the Restoration one of England's best-known physicians, ensconsed in a thriving London practise and endowed with the clout to "persuade people to let him dismantle their dead husbands, wives and children, and even ... the bodies of aristocratic patients. For the first time in the history of medicine, Willis could link the diseases and disorders that people experienced in life to the abnormalities he found in the brains after death."

Zimmer makes a good case for Willis's preeminence as the first modern neurologist, and the book is an engrossing read. But it also begs the question of whether Willis really might have single-handedly antedated the beginning of neuroscience by counteracting the hold of Descartes's erroneous dualism, had he been remembered sooner and better - or whether he was simply a figure of the scientific revolution whose investigations went as far as those of his most perceptive contemporaries, like Steno, and who did not so much look ahead of his time as play his part in it. Zimmer, it must be said, has judiciously relied on the vast literature concerning the scientific revolution in England and firmly placed Willis within his intellectual and political context, brushing throughout fresh, lively portraits of figures central to the history of science and philosophy (not all known to the general public), and adopting the view that the study of the soul in England mirrored, explicitly at times, a political concern with the English nation's health, with the state of its royal head and its relation to the body of its subjects.

Knowledge of the context within which Willis worked matters to any reassessment of his historical importance as an individual who stood out as did Galileo, Harvey, Hobbes, Descartes, Boyle, Locke or Newton. In the heady, bloody years leading up to and encompassing the English Civil War and the Interregnum, he was one of a number of young men in Oxford devoted to the free pursuit of natural philosophy. They eventually would form the core of the Royal Society, which received Charles II's imprimatur in 1660. It was under its aegis that Willis published *Cerebri anatome*. He had it strikingly illustrated by his colleague and friend, the naturalist and architect Christopher Wren, and dedicated it to the Bishop of London, Gilbert Sheldon. To preempt any possibility, in the forbidding atmosphere of the Restoration, that his work might serve what he called the "Schoolhouse of Atheism", Willis assured his dedicatee that it served instead to "unlock the secret places of Mans Mind and to look into the living and breathing chapels of the Deity".

Zimmer minutely recounts what it took for Willis, over nearly forty years, to unlock these "secret places", in an attempt to gain knowledge of what Locke would claim was beyond the capacity of humans to know (ideas in the mind were more reliable than invisible particles and pathways in the brain). Readers are led back and forth between science and politics, starting with graphic scenes of grisly, smelly scientific experiments, dissections of dead criminals and vivisections of live dogs in Oxford college rooms turned into labs or churches, and equally graphic scenes of political chaos, of anxiety, filth, sickness and misery in the England of the Civil War. Religious frenzy and political passions would lead, in 1649, to the decapitation of Charles I, depicted here as a misunderstood, high-minded king who had been insightful enough to befriend and support William Harvey when others dared not, but had not been capable of understanding his own role, his people and the political game itself, closing down Parliament, holding on to the trappings of absolutist rule, and ordering his Archbishop Laud to persecute religious - especially Puritan - dissidents in the name of obedience to the king. Unlike Harvey, writes Zimmer, he "never figured out how to read the hearts of his subjects and instead ended up in a civil war".

Willis himself was born into a Royalist, staunchly Church of England family. He studied medicine at Oxford, after relinquishing, in light of the troubled atmosphere of the early '40s, the initial idea of a career in the clergy. His relatively low social rank forced him at first to work for his studies; as a servant to Mr. Iles, a canon at Christ Church College, he ended up preparing the remedies of Mrs Iles, who knew medical recipes and practised home-grown cures. This was Willis's first encounter with alchemy. Originally revived on the basis of Arabic sources by Paracelsus in the early sixteenth century, and later by Joan Baptista van Helmont, Paracelsian medicine was based on plants and metals, on the elements of salt, sulphur and mercury, and on the idea of the chemical unity of the universe. At university, however, Willis was hearing the same lectures that a Renaissance student might have heard. Zimmer, appropriately enough, begins his book with the ancient sources of the psychology and medicine Willis, like countless physicians before him, was being taught.

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There was nothing new, of course, in his concern with the nature of the mind, and Zimmer broadly recounts how, for centuries, metaphysicians and theologians debated

the soul's substance, its immortality, its relation to the all-too-mortal body. He begins the book with Alcmaeon, who was perhaps the first to claim, around 500 BC, that "all senses are connected to the brain", laying the foundations of a craniocentrism Plato then adopted and transmitted via his influential *Timaeus*, where he described humans as endowed with both a rational, immortal soul housed in the brain and a lower, less noble soul; this lower soul was in turn divided into a heart-based vital part responsible for the higher passions, and a liver-based vegetative part responsible for growth, nutrition, desire and impulse. Aristotle later modified Plato's organism: all living creatures shared an appetitive soul, for breathing, nutrition and reproduction; animals and humans, but not plants, shared a corporeal soul, for perception, sensation, imagination and memory. Topmost was the rational soul, a part of which Aristotle granted to beasts, but whose highest aspects - those pertaining to contemplation, abstract thought and free will - belonged to humans alone. It was located not in the brain, which merely served to cool the blood, but in the heart, which processed all the perceptual information gathered by the senses. The soul was the form of the body, what enabled it to fulfill its functions.

The Roman physician Galen, in the 1st century AD, synthesized Plato, Aristotle and later Greek anatomy, and integrated these with the humoural physiology posited within the earlier, Hippocratic corpus of medical writings. According to humoural doctrine, the organism was essentially made of four humors circulating within the blood, that determined its health, illness, temperament and moods. Galen described particles or "animal spirits" flowing in the blood from the liver to the heart, that turned into "vital spirits" once they passed through the *rete mirabile*, a network of vessels at the base of the brain. Here they served the functions of the rational soul, accounting for all conscious perception and sensation, for voluntary action and emotion, dissolving in the name of physiology any mind-body concern a metaphysician might harbor. Mental faculties - imagination, memory and common sense - were housed in the brain's ventricles, spaces between its hemispheres. Scholastic psychology transmitted this scheme and refined it. From the thirteenth century on, questions pertaining to the materiality of the soul were generally theological; worries about the nature of its incarnation regarded the metaphysics of mind. The brain itself was not an object of study.

Breaches in the system began to appear in the later Renaissance. Anatomical knowledge evolved partly because human dissections - Galen himself was never able to conduct any - became possible. The Paduan anatomist Vesalius, Zimmer recounts, flayed human cadavers in unforgettable public sessions, showing to his audience, for instance, that the *rete mirabile* was absent from the human brain: Galen's specimen had probably belonged to an ox. Vesalius's *De humanis corpore fabrica*, with its extraordinary illustrations, came out in 1543, the very year in which Copernicus's heliocentric planetary scheme was published. Despite these assaults on ancient authority, though, Aristotelians continued to rule nature and the heavens from their university chairs and school pulpits. Humors flowed in the body and the sun circled around the earth. Aristotle's interconnected souls had allowed for a continuum between species; and together with the doctrine of the humors, which sustained the bleedings, leechings and cataplasms of standard, Galenic medical care, they ensured a comfortable cohesion between biology and Christian metaphysics.

Medical practise was still based on the notion of spirits and humours in Willis's time (as it was even in the early nineteenth century), and throughout his life he would remain faithful to these spirits in his practise. He bled patients and treated their ills according to the old notion of a balance between hot and cold, dry and wet. In theory, however, Galenic humours hardly cohered with Harvey's new account of the circulation of the blood, and Willis, as a good Harveian, knew that. Oxford lectures were useless to his thinking; but he would not have to sit through them for too long in any case. When, in 1642, Charles I, along with his court and retainers, took refuge in Oxford from the increasingly hostile Parliamentary armies, a typhus epidemic broke out that ravaged town and country. Lectures stopped; but Willis took notes on the disease. He joined the Royalist forces, which fell to the Parliamentarians in 1646, and when he returned to a ravaged Oxford, he was, in Zimmer's words, "[A] poor, orphaned soldier on the losing side of a civil war", trying for the next decade to survive events which felt to him and his contemporaries "like a national insanity". But the town was also thriving with new ideas: it was "a fizzing vial of spirits, a place where alchemists jostled with Aristotelians, where telescopes were trained at the sky and microscopes at the legs of fleas. Scandalously new ideas about the soul itself bubbled up - not theological ideas so much as scientific ones, even political ones". Willis was welcomed back with a medical degree, and he began his career.

He did not immediately open heads. He remained a poor "Pisse-Prophet" for some years, riding long distances out of Oxford in the company of his colleague Ralph Bathurst to examine his patients, until he befriended John Wilkins, a moderate Puritan and Galilean, whose good relations with Parliament won him a post at Oxford that enabled him to appoint talented scholars and turn into a reality Francis Bacon's earlier dream of a community that would promote the progress of the new science. Christopher Wren - son of the now destitute dean of Windsor and already noted as a prodigy - arrived soon after and began to work for Wilkins. The three men now formed the core of the Oxford Experimental Philosophy Club. Another alchemist of repute, Robert Boyle, was welcomed in 1655; he proceeded to found private laboratories and turned "an informal club into a public testing place for scientific ideas, even welcoming lords and ladies to add more respectability to his experiments", while remaining sceptical of systems and of the very capacity for humans to fully understand God's nature.

Willis began a collaboration with Boyle. His heretofore unofficial research started to yield results. Combining alchemical principles with new corpuscular theories, his long-standing study of fevers culminated in the notion that they were a fermentation of the particles in the blood - a matter of chemistry, not of humors. He conducted his studies of blood along with Boyle, Wren and Bathurst, as well as with newcomers to the Circle such as Richard Lower, who helped Willis with the dissections for *Cerebri anatome*, and Robert Hooke. (Zimmer retells very well the now historical experiments that took place during those years - from the first blood transfusions to Boyle's air-pump - and which led to the notion that the blood processed something in the air that was necessary to life.) In the late 1650s, Willis observed that patients afflicted with what we call meningitis "talked idly, and at random", as he wrote; he began to speculate about the reasons for which a fever could lead to such symptoms.

Soon, he was beginning to look at the brain itself as a "marvelous alembic": "animal spirits" were distilled out of the blood, before travelling throughout the brain and via

the nerves, which he realized were not hollow, as was still believed. In his search for physiological explanations for the mental disturbances of some of his patients, Willis realized that the brains he dissected differed even from Vesalius's descriptions and that a complete anatomy of the brain and nerves was called for. The Restoration helped his research conditions: under Cromwell, Anglicans and Royalists had gathered in Willis's rooms to pray as the "Loyal Assembly", which had become a center of political dissidence, but now his (not-so-secret) church turned into an official dissecting room. Brains, thanks to an invention of Boyle's, could now be preserved, and Willis had the time and freedom to see that ventricles, for instance, were empty spaces; to confirm his notion that the blood circulated within the brain; and to observe what we know as the Circle of Willis. By the time the Royal Society was founded in London, its members' experiments were renowned. *Cerebri anatome* turned out to be a resounding success, and the celebrated physician moved to London, where he began to investigate the soul.

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Willis never gave up on the notion of "animal spirits", using the term to denote corpuscles in the blood that carried information between brain and body. The notion of corpuscules was in fact popular as an alternative to the scholastic foundations of metaphysics, physics and natural philosophy. Zimmer tells us how the priest Pierre Gassendi, in the 1630s, had ressuscitated the atoms imagined by Lucretius and Democritus to depict the universe in terms of particles in motion, flowing through empty space but created by a Christian God at the dawn of time and constituting everything from stones and plants to the - sensitive - soul. Another priest and associate of Gassendi's, Marin Mersenne, had also sought an alternative to Aristotelianism, partly in order to bolster the Church against ever more numerous heresies, and found it in mechanism, the notion that the universe was a machine, designed according to universal mathematical laws. Mersenne had taken a young Descartes under his mantle, who eventually sought to understand all nature in terms of the "clear and distinct ideas" exemplified by mathematics. Here too, the universe, including the human body, was made of matter in motion. Our body was a clock-like, mechanical artifact, replete with - Galenic - spirits communicating sensory information from part to part, and ensuring cognitive operations. Heart and liver were mere organs. The soul, which humans alone possessed - no Aristotelian gradation from plant to man applied in the Cartesian view - was entirely immaterial, unique and indivisible, seated in the brain's pineal gland.

Too heavy an attack on traditional models could of course lead to uncomfortable results. In 1633, the Church had condemned Galileo - who considered himself a good Catholic - to perpetual house arrest on the charge that he refused to claim that Copernican heliocentrism was a hypothesis rather than a truth, thereby displacing the earth from its central place in the created universe. As soon as he heard of Galileo's arrest, Descartes had the publication of his anti-Aristotelian *Le Monde* stopped, just in time. Few people, on the other hand, ever believed Willis's work to threaten the spiritual order. Willis himself was adamant that the cerebral pathways he traced accounted primarily for the corporeal, sensitive soul, and did not downgrade the higher, immaterial, immortal, rational soul - the conscious mind that, still today, seems to elude its own grasp. He agreed with Descartes's clear-cut distinction

between body and soul as little as Steno had respected Cartesian anatomy, and as he continued his investigations, Descartes's mechanistic organism fell apart.

Along with a number of his contemporaries, Willis favored instead Gassendi's view that the sensitive and rational souls were continuous with one another, and he developed this notion in a book he published in 1683, *De anima brutorum* or *The Soul of Brutes, Which is that of the Vital and Sensitive of Man*. He observed - as Steno had - that the soul "understands all things but her Self", as he wrote; but he nevertheless wondered, "in this Age, most fruitful of Inventions ... why may we not also hope, that there may be yet another disquisition concerning the Soul, and with better luck than hitherto? Therefore, however the thing may be performed, I shall attempt to Philosophise concerning that Soul at least, which is Common to Brute Animals with Man".

By imagining that human and animal brains were on a continuum with one another, Willis was stretching the old tradition of comparative anatomy to the realm of the brain, analysing parts and correlating them with functions, prefiguring, in Zimmer's view, our post-Darwinian notion of the mind as an evolved organ, whose functions we study today by correlating them with the visible, live brain seized by MRIs. For Willis, it was only by practising "Psycheology", by studying the corporeal soul common to animal and man, dependent on the body and essential to its life and functions, that one could differentiate it from the "Rational Soul, Superior and Immaterial". But having separated the two, he proceeded to study the brains of his dead patients to understand their loss of speech, or their delirium. He understood, correctly, that the cerebellum was responsible for involuntary motion such as the heartbeat (we know today that the brainstem is involved too), but also that higher functions such as imagination and language were processed in the cerebrum: the rational soul too was housed in the brain, in the corpus callosum, where it responded to the spirits transmitted by the sensitive soul, to its perceptions and sensations. These spirits in turn could change thought-processes, moods and emotions; in cases of delusions, for instance, distorted spirits drew distorted paths in the cerebrum. The brain was a chemical organ wholly accountable for the vagaries of mental life.

Willis was, in fact, engaged in naturalizing the mind. He was not alone in this; materialism and libertinism were on the horizon, and Gassendists like Claude Perrault or Guillaume Lamy in France (from which Zimmer chose to stay away in this book) were asking similar questions. Zimmer calls Willis "a backward-looking revolutionary" who "preserved the old medicine within the new science". Indeed his old-fashioned vocabulary justified his conservative, wholly Galenic bedside methods and perhaps explains why he was embraced for his insights by both Church and state. But while Zimmer wants to show, through his grasp of the current state of neurosciences, that this conservative stance belies a modern view of the brain and anticipates many of our assumptions about its workings, as well as many of our questions about its study, it does Willis no disservice either to play down the revolutionary nature of his undertaking. This was a man, after all, who remained a Royalist against many odds, who bled his patients just as did every other physician, who embraced old-fashioned, folk remedies - as is clear for instance in his *Plain and Easie Method for Preserving Those that are WELL from the Infection of the PLAGUE, AND For Curing such as are Infected With it* written in the plague year of 1666 - and who adopted the "animal spirits" of Greco-Roman medicine.

Of course what he understood as these "animal spirits" travelling through the brain and nervous system can be seen, as Zimmer suggests, to be akin to today's picture of electrical impulses travelling between neurons. Willis's spirits fulfilled different functions in each area of the brain, and, as Zimmer observes, we do indeed know today that specific functions are broadly localized. Willis, furthermore, did try to establish correlations between psychological disturbances and events in the brain, and the popularity of psychotropic drugs does, as Zimmer suggests, prove this insight right, at least partially. Willis's theoretical innovations were real and, to tell by his worldly success and grand funeral, recognized by his peers.

But one must also make something of the fact that Willis himself did not find a viable way of applying his theories to his patients. What Zimmer has done in tracing this much-needed genealogy of our own "Neurocentric" concerns, is in fact to show us how historically deep remains the gap between theory and practise where our self-understanding is at issue. "animal spirits" were, and perhaps have always been metaphorical names for substances whose exact workings, in the end, remain as mysterious to us as they were to Galen, Descartes or Willis himself. Causal correlations are not exhaustive of human psychology; however much we are constituted by our neuronal connections and determined, in some ways, by our neurotransmitters, our lives are not satisfactorily explainable by them. Willis, in leaving intact the immaterial soul just as did his most illustrious contemporaries, acknowledged that better than we know how to do now that materialism is inescapable. For this reason, there may have been no need for Zimmer to overstate the case of Willis as forerunner, rather than to conclude, more conservatively but perhaps more provocatively, that "neurologie" is all too good at preserving old questions within new bottles. To know just how old these questions are can only help the most cutting-edge of sciences ask them better.