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A Kuhnian Analysis of Willis

In Louis Armstrong's timeless song "What a Wonderful World", he laments "I hear babies cry/I watch them grow/They'll learn much more/than I'll ever know." This concept of a progression of knowledge is a common one. People often look to the future as a time with better technology, more opportunities, and more credible knowledge than in the past. The scientific philosopher Thomas Kuhn, however, is one who would reject this concept in light of his argument that things such as science and knowledge do not progress towards any greater truth.

Kuhn wrote extensively on the history of science from the perspective of a philosopher. One of his most prominent (and most hotly debated) theories was that an examination of the history of science reveals a series of paradigm shifts. He claims that there are periods of normal science, during which one paradigm is accepted and experiments are carried out with the guidance of said paradigm. At one point in normal science, a crisis occurs and the structure of the paradigm can no longer withstand the weight of the crisis. This leads to a paradigm shift, during which a new paradigm is sought that will be more efficient at solving the problems of the scientific field that it governs. Kuhn cited works like Newton's *Principia Mathematica* and Ptolemy's *Amalgamest* as containing good examples of paradigms¹. Not only did Newton and

¹ Bird, Alexander, "Thomas Kuhn", *The Stanford Encyclopedia of Philosophy* (Spring 2013 Edition), Edward N. Zalta (ed.),
<<http://plato.stanford.edu/archives/spr2013/entries/thomas-kuhn/>>.

Ptolemy delineate the terms of their laws and theories, but they also described how those theories could be applied to solve important problems within their fields. This is, to Kuhn, the crux of a paradigm; the one that would resist a crisis the longest is the one that offers the most efficient problem-solving methods.

Oxford-educated Englishman Thomas Willis received his bachelor of medicine degree without the training of even a modern-day pre-med college graduate, and yet he would go on to become one of the most influential physicians in history. His work during the seventeenth century is considered revolutionary, but would Kuhn agree?

The major achievement of Willis' medical career is his examination of the brain's functional organization. He became interested in the brain when he joined a circle of natural philosophers at Oxford called the *Virtuosi*. These men were particularly influential to Willis because they were willing to engage in criticism of Aristotle, which was uncommon at the time. In his future work, Willis would both accept and reject portions of the Aristotelian tradition. For instance, he was appointed Sedleian Professor of Natural Philosophy at Christ Church, Oxford, which required him to present two lectures per week rooted in that very tradition. He chose to use this appointment to study the sense, nerves, and "affections of the soul" in a way that probably would have been unsanctioned by his predecessors in the professorship². However, he also engaged in autopsies of animals like pigs, horses, goats, and sheep, just as Aristotle did. In addition, Willis benefitted from a rapid shift in Oxford's academic environment that saw the exit of most of its highly conservative (and Aristotelian) faculty members in favor of professors with forward-looking perspectives. The old ways of an Oxford education, which had

² Finger, Stanley, *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. (88). New York: Oxford University Press. 2000.

included resolving conflicts by finding relevant passages in the writings of Aristotle or the physician Galen, were abolished. This led to older ideas about neurology, like the notion that perception, cognition, and memory are all associated with different ventricles, being displaced.

When the history of the brain is written in medical textbooks, Thomas Willis is usually credited with the discovery of how the brain's organization relates to its functions. The major book associated with this work is *Cerebri anatome*, published in 1664 and lauded as the foundation for research on the anatomy of the central nervous system³. In his book, Willis described the circulation of blood in the brain and the place where major cerebral arteries meet, which today is called the Circle of Willis⁴. He believed that memory was located in the outer portion of the brain, specifically the cerebrum; this hypothesis was based upon his comparison of the human cerebrum's deep grooves and the animal cerebrum's smooth exterior. This is a departure from the previous theories posited by men like Descartes, who thought that ventricles played a critical role in the brain's higher functions and made them central to his pineal theory. Willis said that the ventricles were empty and played no part in memory, cognition, volition, or imagination⁵.

Thomas Willis also examined, named, and analyzed the corpus striatum, which is a structure streaked with grey and white matter. He thought that the striated corpus was related to movement, specifically that it contained channels through which animal spirits could travel and induce movement. He also associated it with sensation, saying that it

³ <http://galileo.rice.edu/Catalog/NewFiles/willis.html>

⁴ <http://www.nlm.nih.gov/medlineplus/ency/imagepages/18009.htm>

⁵ Finger, Stanley, *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. (93). New York: Oxford University Press. 2000.

received sensory inputs that could trigger voluntary or involuntary motor outputs⁶. Here, his beliefs contrast those of the Church, which believed at the time that the first ventricle was the locus of all sensation.

It is indisputable that Thomas Willis contributed much to the world of science through his observations and experiments. However, when one begins to look at his work- specifically with the functional organization of the brain- from a philosophical standpoint, his place in the history of science becomes less prestigious. Thomas Kuhn's extensive writings on the philosophy of science and the nature of scientific paradigm-shifts provide the basis for our analysis of Willis. The fundamental question that we begin our analysis with is "Was Thomas Willis' work the cause of a paradigm shift?" A paradigm shift is hallmarked by a transition from normal science (which contains a universally shared set of assumptions about the way things are) to that worldview being completely shattered. How was Willis' work different from the work of those before him, and was it different enough to make it radical?

René Descartes is the man to whom Willis is most often compared. Descartes had a profound interest in the brain and in what capacity the soul existed within the brain. Willis discounted many of Descartes' most prominent theories, particularly the pineal theory. Descartes claimed that the pineal gland was attached to the brain by delicate fibers, which allowed the rational soul to shake the gland and move the animal spirits through certain pores in the walls of the ventricles. From the ventricles, the spirits would

⁶ Finger, Stanley, *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. (93). New York: Oxford University Press. 2000.

travel through the nerves and execute the will of the soul⁷. Descartes also viewed the body like a machine that doesn't need a soul to live and move. He said, "We shall have no more occasion to think that our soul excites the movements- those which we do not experience to be presided over by our will- than we have to judge that there is a soul in a clock which causes it to show the hours."⁸ Descartes argued that perception could become action without the intervention of the soul, because each of the body's movements are nerves opening pores in the ventricle. However, he made it clear that the difference between animals and humans was that humans *did* have a soul.

Willis completely discarded Descartes' celebrated pineal theory, and he did so by using much more sophisticated means of research. Descartes dissected the brains of several animals, made crude drawings, and analyzed his findings due to the information he read in an anatomy textbook⁹. Willis also performed dissections, but he used human brains taken from newly executed criminals and had a degree in the field of medicine. He shied away from the emphasis on the ventricles, which he saw as empty and unimportant to the workings of the brain. He also pointed to the striated corpus as the place where the brain processes sensations, instead of the pineal gland.

Using Kuhn's theory of paradigm shifts, Willis' rejection of Descartes' pineal theory would qualify as a paradigm shift. In his research, Willis set out to learn as much about the brain as he could, and he would "unlock [the secret places of man's mind] not

⁷ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (37). New York: Free Press, 2004. Print.

⁸ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (34). New York: Free Press, 2004. Print.

⁹ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (36). New York: Free Press, 2004. Print.

by reading Aristotle or Galen but by reading Nature's book.¹⁰ Willis had learned from his time at Oxford that the classics did not always provide the perfect solution, and so he chose to simply rely upon observation and experimentation. Willis did acknowledge several influences, including Dr. William Harvey, who first explained how blood is circulated in the body. Was Willis operating under a paradigm when he completed his research? Yes, because although he did not support the findings of Descartes, Aristotle, or Galen, he was still conducting his research under the guidance of their theories to see if they could be disproved using evidence. The fact that Willis was seeking to displace a paradigm does not mean that he was operating outside of the paradigm. What he did find led to what can be called a paradigm shift.

When determining whether or not Willis' work was the catalyst for a paradigm shift, one would be remiss in not considering his role in the appropriately named "Oxford Circle". This was a group of men that included Robert Hooke, Christopher Wren, William Petty, and other Oxford academics. These men did not accept the teachings of Aristotle and his peers as canon, and were seeking to create an environment in which new ideas were free-flowing, accepted, investigated, and respected. They were often accused of wanting to destroy the concept of a university altogether, when in reality they simply wanted to "replace Aristotle and Galen with Galileo, van Helmont, and Harvey."¹¹ Willis worked closely with many of these men, particularly Christopher Wren, who illustrated most of Willis' writings. These men knew that a "changing of the guard" needed to occur, and so they were trying to find the evidence to prove it. What does this mean for

¹⁰ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World.* (174). New York: Free Press, 2004. Print.

¹¹ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World.* (122). New York: Free Press, 2004. Print.

the analysis of Willis' work as a paradigm game-changer? It means that although his findings regarding the human brain were new and changed the way science was done, it served to widen the period of crisis instead of creating a new one. Thanks to the Oxford Circle, the framework of the old paradigm was already weakening, and Willis' work provided the spark that burned down the whole structure.

Although the presence of the Oxford Circle means that Willis didn't "shatter" the existing worldview, he certainly did refute its credibility. This is mostly due to his discovery of the Circle of Willis, which is a structure in the brain that ensures that the entire brain is supplied with blood, even in the case of partial damage to the structure. In addition, Willis completely dismissed Descartes' pineal theory by searching for it in animals; if Descartes' claims were true, then the pineal gland would be missing from animals because animals lack rational souls. Willis found the gland in the brains of birds and fish, which led him to completely discard the ventricles as "'a mere vacuity' about which there was 'no reason we have to discourse much.'¹²" By dissecting a multitude of brains, Willis began to form a picture of the organ as being made up of several distinct parts that each played different parts. This picture was aided with his observation of the cerebrum, which in humans is large and deeply ridged but in animals is smaller and smooth. The cerebellum is almost identical in humans and animals, and Willis believed that its simple structure meant that it had a simple purpose, which was to create spirit that traveled down to the organs and kept those organs moving. He said, "The Spirits inhabiting the Cerebel perform unperceivedly and silently their works of Nature without

¹² Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World.* (178). New York: Free Press, 2004. Print.

our knowledge or care.¹³” Through an experiment with a dog, Willis proved that the cerebellum controlled the lungs and heart. These discoveries were paradigm-changing in two ways. Aristotle had categorized motion as voluntary or involuntary, but Willis was proving that they are divided into different parts of the nervous system. Through this experiment, Willis also argued that the soul cannot reside in the heart because the heart is simply following the commands of the spirits sent from the brain; thus, Willis placed the soul in the brain¹⁴. Descartes’ main definition of the human body was that it was a union of a rational soul with a physical machine, but Willis’ accurate depictions of the brain supported his claims that spirits travel through the flesh of the brain into the body to produce involuntary reflexes.

Others in the field of science immediately and widely hailed Willis’ work with the brain, which resulted in the publication of his book *The Anatomy of the Brain and Nerves*. His fame extended well past his lifetime; anyone in the following centuries who wanted to be considered an expert on the brain could not escape reading *Anatomy*, and Christopher Wren’s accompanying illustrations were reprinted in anatomy textbooks well into the twentieth century. According to Zimmer, “Willis’s team had... created a unified treatment of the brain and the nerves. An erratic, error-ridden study of the brain became a rigorous, experimental science.¹⁵”

Once Willis’ conclusions about the brain were accepted, he and others began to examine how those conclusions could be applied to other questions, and what new

¹³ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (179). New York: Free Press, 2004. Print.

¹⁴ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (180). New York: Free Press, 2004. Print.

¹⁵ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (187). New York: Free Press, 2004. Print.

questions were raised. Robert Lower, who had worked with Willis when he was studying the brain, put one of these queries forth. He wanted to know why the heart needed so many nerves if, as Harvey claimed and Willis provided evidentiary support for, blood moves through the body on its own power. By examining the muscle fibers of the heart, Lower was able to determine that the heart didn't need blood inside its chambers to beat, and that the spiral construction of the fibers meant that they compressed so violently that everything in the heart's chambers was expelled¹⁶. He concluded that the heart was nothing more than a muscle, which further supported Willis' claim that the soul was located in the brain and not the heart.

Interestingly, one part of Lower's experiment that did not support Willis' writings in *Anatomy* was his exploration of why blood is red. Willis and others in his peer group believed that prior to entering the arteries, blood turns red in the right side of the heart. Lower's experiments, which were completed by a student named John Mayow, showed that blood turns red when it is exposed to air¹⁷. Willis was alive to see this discrediting of his theory, and he accepted it as an indication of error in his original observations. However, the paradigm remained stable, because the process of blood turning red does not affect the soul's presumed location in the brain nor the functional organization of the brain. The paradigm was flexible enough to withstand this change without collapsing, which Kuhn would say means it is an efficient and strong paradigm.

Willis' work did inspire some criticism, but these criticisms served to point out further research that could be done under the new paradigm. One of his critics was

¹⁶ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (212). New York: Free Press, 2004. Print.

¹⁷ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (214). New York: Free Press, 2004. Print.

Nicolaus Steno. Steno pointed out that it was speculative of Willis to pinpoint the locations of common sense, imagination, and memory, and he asked “Who is able to tell us whether the nervous Fibers begin in the Corpora Striata, or if they pass through the Corpus Callosum all the way to the cortical substance?¹⁸” Steno thought that Wren’s diagrams, based upon Willis’ experimentations, were exemplary but that the accompanying analyses needed to be grounded in more objective research.

It’s clear to most historians of science that Willis should be valued for his contributions to understanding the brain, but also for his ability to make his discoveries exciting enough to inspire other scientists to take them further. His work with the brain led to other scientists conducting more autopsies on humans, because they saw that Willis learned more from the human brain than Descartes did with the brains of animals. People continued to experiment on animals, partially due to the limitations on experimenting on humans, but partially because Willis learned much from his work with animals and knew there was still value in using them¹⁹. In addition, scientists were excited about Willis’ observations about the nervous system and continued to explore the complex network of nerves located in the human body.

In his research, Willis made one important distinction that led to the destruction of Descartes’ paradigm and the acceptance of his own. This difference is the rejection of Descartes’ claim that animals don’t have the capacity to think or remember. This allowed the scientists who inherited Willis’ research to study things like memory,

¹⁸ Finger, Stanley, *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. (98). New York: Oxford University Press. 2000.

¹⁹ Finger, Stanley, *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. (99). New York: Oxford University Press. 2000.

thought, and imagination using animals²⁰. Essentially, instead of loading it with metaphysical language, Willis' reduction of the study of the brain to its physical elements made the paradigm easier to accept and clearly demarcated the path to future research under the paradigm. He mentioned the soul as part of his writings and was interested in the topic of souls, spirits, and other mystical elements, but he took science in a much more practical direction.

Willis emphasized observation and experimentation in his research, which indicated to his peers and students that the best foundation for any scientific work is physical evidence. Descartes studied the brains of animals, read his anatomy textbook, and made metaphysical assumptions about an organ that he had never even seen in real life. On the other hand, Willis made his more accurate conclusions by spending almost two years investigating the brain by conducting dissections and experiments. This was the beginning of a new age in scientific research that involved an emphasis on objective observation. In fact, the emphasis was so strong that the Royal Society tried to encourage Robert Hooke to redo an experiment that involved cutting open the windpipe and chest of a still-living dog to see if there was a connection between air and blood. Due to the extremely graphic nature of the experiment, Hooke refused to repeat the procedures but relented three years later²¹. To him, the potential benefits to the world of science outweighed the horror of torturing a dog. This experiment could trace its origin back to conclusions that scientists made based on Willis' work; although Willis only used organs

²⁰ Finger, Stanley, *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. (99). New York: Oxford University Press, 2000.

²¹ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (213). New York: Free Press, 2004. Print.

that had been harvested from patients who died or executed criminals, his moral standard was not accepted by all of his peers.

Although Willis' works inspired his fellow scientists to be more focused on the experimental aspects of science, they also caused the thought-world of his peers to become completely transformed. This extended to the area of philosophy, where Willis' student John Locke wrote essays whose ideas can easily be traced back to Willis. The most prominent example is Locke's famed theory of the mind as a *tabula rasa*, or blank slate, when a baby is born²². Based on his observations concerning the brain and its perception of sensations, Willis wrote that the brain contains nothing that was not first in the senses. It also extended to the area of theology. In Willis' book *The Soul of Brutes*, he summarized his research on the soul, specifically stating that people had an immaterial soul and a soul comprised of particles of spirit. He permanently and exclusively located the soul in the brain and claimed that it could only experience the world through the nerves. Zimmer says that Willis "abandoned Descartes's careful compromise, handing even more of the rational soul's work to a material soul."²³ Willis was worried that he would be accused of atheism, but clergymen embraced Willis' theories. They could now point to such phenomena as speaking in tongues and attribute it to a physical disorder causing disordered views of reality, instead of possession by the Devil.

There is a reason Descartes only used a few crude drawings and the brains of animals to make his conclusions; before Thomas Willis, the brain was not of ultimate importance to anatomists. Willis' choice to focus his research on the brain led to

²² Finger, Stanley, *Minds Behind the Brain: A History of the Pioneers and their Discoveries*. (99). New York: Oxford University Press. 2000.

²³ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (228). New York: Free Press, 2004. Print.

scientists expanding their horizons, so to speak, in terms of what their experimental focus was. Once it was seen that the heart was not the locus of the soul, and that the brain was much more complex than originally thought, scientists realized that they could learn much from direct observation of the brain. It was exciting and new to them that they could learn things about the rational soul, which was immaterial, simply by autopsying an organ from the human body. Willis' ideas were so clearly defined and accurate that scientists began to believe they could truly learn about consciousness, reasoning, philosophy, and even theology from examining the brain. Although Willis was concerned that people would conclude that he was an atheist from his writings, in actual fact he helped to simultaneously revive and transform the fields of science, philosophy, and theology.

Although Thomas Willis is often seen as the father of the Neurocentric Age, today his ideas are simply a murmur in the background of scientific discussion on neurology. Most of his ideas were taken by students like Locke and either revised or discredited, but his work formed the four foundational pillars of neurology, and those pillars still stand today. They are: the animal spirits that travel through the brain that govern everything (today known as electrical impulses), the spirits complete the soul's different wills in different parts of the brain (today known as the different neural networks within the brain), the similarities between human and animal brains (today seen as a signal of our physiological similarities), and curing the soul's diseases (which created the modern field of psychopharmacology)²⁴. Willis' paradigm is no longer the model of scientific neurology that it once was, but it has not been replaced by a new and radically different

²⁴ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (264). New York: Free Press, 2004. Print.

paradigm. Instead, there have been modifications to Willis' beliefs. In Locke's *Essay Concerning Human Understanding*, he takes Willis' penchant for experiments and observations and makes it a fully formed philosophy that is the root of today's scientific method. The essay also contains Locke's arguments that people lose their sanity because their ideas are erroneously connected within their brains. This is very similar to Willis' belief that the spirit particles can be altered and this is what causes people's rational souls to see false images of the world²⁵.

One problem that Willis left behind is a paradox that still stumps modern neurologists. This is the idea that humans have two souls; a sensitive soul that is material and therefore subject to damage, and a rational soul within the brain that is immortal. The issue becomes apparent when one considers how Willis could claim that the rational soul could be negatively affected by some mental diseases like stupidity²⁶. How could the rational soul, immaterial and immortal, be controlled by a physical disorder within the brain? Today, neuroscientists would say that the self is incapable of being separated from the brain, and that it is prone to disease or damage if the brain itself is damaged. Scientists today are studying the rational soul, which encompasses concepts like consciousness and reasoning, in the same way that Willis studied it in the seventeenth century.

What can we conclude from this analysis of Thomas Willis and his work regarding the functional organization of the brain? There have been several points in this analysis that I have tied Willis' works to Thomas Kuhn's ideas about paradigm shifts in

²⁵ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (256). New York: Free Press, 2004. Print.

²⁶ Zimmer, Carl. *Soul Made Flesh: The Discovery of the Brain- and How It Changed the World*. (266). New York: Free Press, 2004. Print.

scientific history, but it is time to make fortified connections between the ideas of the two men. As previously noted, Kuhn's description of a paradigm shift is that it occurs after a period of normal science, it shatters the universally held worldview, and it is eventually replaced with a radically different paradigm. After examining the works of Thomas Willis in the context of his predecessors, his peers, and his successors, I would argue that his work regarding the functional organization of the brain does qualify as a paradigm shift. I will proceed to break down each part of the definition of a paradigm shift and relate them to Willis.

Willis' work did not come to fruition during a period of normal science. As evidenced by his participation in the "brain trust" of the Oxford Circle, Willis was not the only scientist dissatisfied with the current neurological theories as put forth by Descartes. He was surrounded by other academics that were trying to make science more accurate and accepted, especially amongst the religious who were scrutinizing the Circle's every written work for signs of atheism. Even during Willis' school days, the professors at Oxford who had been set in the ways of Aristotle and Galen were replaced with newer scholars with fresh ideas about scientific discovery. Although Willis' work took place in a period of crisis, it was not the catalyst for that uncertainty.

The conclusions that Willis made about the brain and its role as the home of the soul were immediately and pretty much universally accepted, and his research inspired other scientists to answer problems that were either made easier to solve or raised by his findings. Based on the research that occurred after Willis began writing about the functional organization of the brain, I would say that his work did create a new paradigm under which future neurological research was done. Scientists took not only his ideas

and began to use them to solve other problems, but they also accepted his emphasis on research and observation as standards that they should use in their own research. His findings stabilized the period of crisis and gave scientists a more satisfactory paradigm that was efficient at problem-solving. Beginning with his student John Locke, Willis' paradigm has been modified throughout the years as technology has continued to advance and as scientists solve the problems raised by his work. However, his paradigm has never been replaced with a radically different or markedly more efficient one; almost four hundred years later, the findings of Willis live on and the Neurocentric Age is still firmly in place. Thomas Kuhn believed that the strongest paradigm is that which resists a crisis the longest because it is the most efficient at problem-solving. In the case of Thomas Willis and his research regarding the functional organization of the brain, Kuhn would certainly say that a paradigm exists that, upon its inception, caused a shift from one paradigm (Descartes') to another (Willis').

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