Transcranial color-coded duplex ultrasonography of the circle of Willis
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History of the circle of Willis
The vascular interconnections at the base of the brain are known to every medical student as 'the circle of Willis' (Figure 1). The arterial anastomosis (Figure 2) was named in honor of Thomas Willis, despite the fact that it had been both described and illustrated prior to the publication of his masterpiece: *Cerebri Anatome: cui accessit nervorum descriptio et usus* (the anatomy of the brain and the description and use of the nerves) in 1664. In this book, Willis set forth, among other things, a method for the removal and dissection of the brain; a new numbering and grouping according to the function of the cranial nerves; extensive descriptions of the basal ganglia, brain stem, and cerebellum; and detailed schemes of the vagal and sympathetic nerves supplying the viscera. But of all the observations in Cerebri Anatome, the most significant are those relating to the cerebral circulation. Willis presented in his Cerebri Anatome the first approach to a functional anatomy of the cerebral circulation. He gave an accurate anatomical description of the arterial circle at the base of the brain and of the arterial vessels bringing blood to the circle and (what has been less well appreciated) he also recognized the important functional significance of this unique vascular anastomosis. Willis was not the first to refer to the anastomoses of the arterial vessels on the base of the brain, nor did he claim that he was. The discovery of the arterial 'circle' at the base of the brain has been a slow process from approximately 1560 onwards, and was largely due to the combined labours of Gabriele Fallopio, Giulio Casseri, Johann Vesling, Johann Jakob Wepfer and Thomas Willis, each in turn making important contributions to its elaboration.

Gabriele Fallopio (1523-1562) was the first to give a reasonably correct description of the arterial ramifications at the base of the brain. Fallopio, whose name is connected with the Fallopian tubes leading from uterus to ovaries, was a student of Vesalius (1514-1564), the Belgian anatomist who was the founder of modern anatomy. In 1551 Fallopio was offered and accepted the famous chair of anatomy at the university of Padua in Italy, the center for western medical instruction in those times. In his *Observationes Anatomicae* (1561) Fallopio
described in great verbal detail, but without an illustrative legend, all of the arteries involved in the anastomosis and their relative contribution. He clearly described the union and later division of the vertebral arteries, and the union of the inferior rami of the carotid arteries (corresponding to our anterior cerebral arteries). He also described about two-thirds of a posterior communicating artery, but it had only indirect connection with the external branch of the carotid (corresponding to our middle cerebral artery), through a network of small arterioles between them. Although Fallopio clearly described the posterior communicating artery, he failed to see its significance in completing a functional vascular loop. Fallopio’s description much resembles that in the explanatory legend of Giulio Casseri’s (c. 1552-1616) illustration almost seventy years later. Casseri was professor of anatomy and surgery at the university of Padua from 1604. His elegant copperplate engravings Tabulae Anatomicae were incorporated after his death in De humani corporis fabrica libri decem of Adrianus Spigelius (1567-1625), which publication was effected in 1627.

A more satisfactory but still inaccurate illustration of the circle of Willis was published within Johann Vesling’s (1595-1649) second edition of Syntagma Anatomicum in 1647. Johann Vesling first worked in Minden in Germany and later became professor of anatomy in Padua. His engraving portrays a fairly obvious, almost schematic, arterial circle, but communication between the anterior cerebral arteries is questionable and no mention of a union between these arteries was included in the text. Another weakness of the illustration is that it shows one vessel extending from the basilar artery to the internal carotid on either side. Vesling had either shown the posterior cerebral and posterior communicating arteries as being of uniform diameter or had omitted the posterior cerebral arteries altogether, neither of which conveys the ‘normal’ configuration of the circle.

In 1658, six years before the publication of Willis’ Cerebri Anatomie, Johann Jakob Wepfer (1620-1695) of Schaffhausen in Switzerland, described in complete and accurate verbal
detail the anastomoses that make up the circle in his book *Observationes anatomicae ex cadaveribus eorum, quos sustulit apoplexia cum exercitatione de ejus loco affecto*. Wepfer studied medicine at the university of Padua and was the first to identify postmortem signs of bleeding in the brains of patients who died of apoplexy. In ancient times stroke was called apoplexy, a general term that physicians applied to anyone suddenly struck down with paralysis. From autopsy studies Wepfer gained knowledge of the carotid and vertebral arteries that supply the brain with blood. He also was the first person to suggest that apoplexy, in addition to being caused by bleeding in the brain, could be caused by a blockage of one of the main arteries supplying blood to the brain. Although quoted by some as the true discoverer of the circle before Willis, Wepfer did not make mention of the functional importance of the structure nor did he provide an illustration of his own, referring instead to that of Vesling with relevant corrections.

Thomas Willis had as pupils men who went on to brilliant careers. They included Richard Lower (1631-1691), who performed the first blood transfusion and explained the structure and action of the heart and became the most celebrated physician in London for a while, and Christopher Wren (1632-1723), who became professor of Astronomy and England’s most distinguished and prolific architect when his plans were accepted for the reconstruction of the world’s largest cathedral, St. Paul’s, after the ‘great fire’ of London of 1666. Lower cooperated with Willis in his researches on the brain, performing most of the dissections and vivisections. In the preface of *Cerebr i Anatome*, Willis calls Lower a ‘highly skilful Anatomist . . . the edge of whose Knife and Wit I willingly acknowledge to have been an help to me for the better searching out both the frame and Offices of before hidden Bodies’. They dissected and vivisected ‘whole Hetacombs* almost of all animals, in the Anatomical court’, including horses, sheep, calves, goats, pigs,

*Figure 3. ‘Shews the Basis of an humane Brain taken out of the Skull, with the Roots of the Vessels cut off’. From Willis’ *Cerebr i Anatome: cui accessit nervorum descriptio et usus*, 1664.*
dogs, cats, foxes, hares, geese, turkeys, fish and a monkey. They also dissected humans. On Wren, who made the drawings for Cerebri Anatome, Willis said: "Dr. Wren was pleased out of his singular humanity; wherewith he abounds, to delineate with his own most skilful hands many Figures of the Brain and Skull, whereby the work might be more exact".

Thomas Willis added little that was new to Wepfer's description, but he gave the first indisputably complete illustration of the circle (Figure 3). Wren clearly shows the arterial circle and cranial nerves in the context of a well-proportioned brain. All elements of a complete circular configuration are shown. All of the component vessels of the circle have been illustrated as sharing a similar diameter which, especially in the case of the normally fine posterior communicating arteries, would present a rare finding. Wren did not include in his drawing other vessels that normally lie in the proximity to the circle such as the superior cerebellar arteries and the posterior inferior cerebellar arteries, and he shows the posterior cerebral arteries as dwindling upon leaving the circle. In spite of these inaccuracies, the total pictorial presentation of the brain and, in particular, of the relationship between blood vessels and cranial nerves, is superior to those of his predecessors. It is possible that some of the oversimplifications and omissions were employed by Wren as a means to create a more stylized view intended to emphasize the important circular configuration, known by Willis to be of functional significance. Willis' description of the arterial anastomosis is in part as follows: "The Vessels of the Brain more aptly represent, and are themselves seen better and more distinctly, if you first squirt into the Carotidick Artery some black liquor. The Vessels interwoven within the thin Menix or Pia Mater are Arteries and Veins. The Arteries are four, viz., two Carotides and two Vertebrals. Out of either side of the Tunnel, the ends of the cut Carotidick Arteries shew themselves, the trunks of which ascending upwards, are presently diffused from either side into the anterior and posterior, or fore and hinder branch. Either pair of these inclining one towards the other, are mutually conjoyned: moreover, the posterior branches so joined, are united with the Vertebral branches (growing together first into one trunk)"

While it is clear that the pre-Willisian anatomists recognized a circle, or produced near-misses, it is doubtful whether they saw the point of this unique vascular arrangement. There is no question, on the other hand, that Willis, in addition to giving a clear description of the circle and of the 'fourfold Chariot' of arterial vessels bringing blood to the circle, clearly recognized its important functional significance. He saw these four large arteries and their 'mutual conjoynings' on the base of the brain as the basis for insuring adequate irrigation of the brain under various physiological and especially pathological conditions. He supported his surprisingly modern insight into the principle of collateral circulation to the brain by intravascular injection of coloured dyes and by ligation in animals of blood vessels supplying
the brain. When he "squirted oftentimes into either artery of the carotids, a liquor dyed with Ink". he found on examination that all parts of the brain and cerebellum were "imbued with the same colour". After a similar injection, as noted by Lower, they observed that the india ink came back down the opposite carotid, clearly by way of the circular anastomoses, before coming out the jugular veins. In discussing this Willis first suggests that the function of the circle is to mix the blood before its distribution to the brain, but on a later page in his Cerebri Anatome adds: "But there is another reason far greater than this (i.e. mixing the blood) of these manifold ingraftings of the Vessels, to wit, that there may be a manifold way, and that more certain, for the blood about to go into divers Regions of the Brain, laid open for each; so that if by chance one or two should be stop'd, there might easily be found another passsage instead of them: as for example, if the Carotid of one side should be obstructed, then the Vessels of the other side might provide for either Province...Further, if both the Carotids should be stop't, the offices of each might be supplied through the Vertebrals".

A case report published in Cerebri Anatome on a man who died of a mesenteric tumour, who in life had no neurological symptoms shows that Willis was fully aware of both the anatomy and the physiological importance of the circle: "...When his skull was opened we noted amongst the usual intracranial findings, the right carotid artery, in its intracranial part, bony or even hard, its lumen being almost totally occluded: so that the influx of the blood being denied by this route, it seemed remarkable that this person had not died previously of an apoplexy: which indeed he was so far from, that he enjoyed to the last moments of his life, the free exercise of his mental and bodily functions. For indeed, nature had provided a sufficient remedy against the risk of apoplexy in the vertebral artery of the same side in which the carotid was wanting, since the size of this vessel was enlarged, becoming thrice that of the contralateral vessel ...". Finally, Willis correctly interpreted that patients who had suffered only slight evidence of neurological deficit during life, despite closure of even two of the four main arteries, as disclosed at autopsy, were able to do so by reason of the collateral arterial channels, so that the remaining vessels were able to "supply or fill the channels and passages of all the rest".

Thomas Willis never claimed to be the first to discover or describe the arterial circle at the base of the brain, nor was he deemed as such by his contemporaries or immediate successors. His name was not used in association with the anastomosis until the late eighteenth century when Albrecht von Haller (1708-1777), who had studied medicine at the university of Leiden under Boerhaave and who became professor of anatomy, surgery and botany at the university of Göttingen Germany, in his book Bibliotheca Anatomica (1774), speaks of the "circulum qui dictur Willissii".
While the term ‘circle’ implies the functional role of this arterial anastomosis, it is of course quite inaccurate anatomically. Strictly speaking, it is a nine-sided structure (not seven-sided, as sometimes noted), and the importance of the anomalies which can occur at the site of any of those nine segments makes it convenient to refer to the structure as a nonagon, or perhaps more simply, ‘polygon’, a term used commonly in the French anatomical and neurological literature. Since Willis in any case did not himself introduce the term ‘circle’ it would seem appropriate to refer to the structure to which he assigned physiological and pathological significance, as ‘the polygon of Willis’.

Although others had described and illustrated this particular anastomosis before him, Willis brought a new understanding to the subject and demonstrated his wealth of knowledge within the pages of Cerebri Anatome, justifying the connection eventually made between his name and the circle. How far Willis had come in clarifying the anatomy and physiology of the cerebral circulation as compared to previous authors can perhaps be most clearly demonstrated by going back to the scheme of the cerebral circulation depicted by Vesalius in 1543. The dural sinuses and the cerebral veins are well shown but the carotid artery and jugular vein join the transverse sinus, an anatomical error which could lead only to a physiological calamity. Clearly Vesalius had not grasped any true idea of the cerebral circulation which was later put forward so well by Willis. Understandably then, Cerebri Anatome provides a landmark in the history of neurology, setting off the transition between medieval and modern notions of brain function. Thomas Willis practically refounded the anatomy and physiology of the brain and nerves. He collated bedside observation with anatomical fact. Willis put the brain and the nervous system on their modern footing so far as that could be then done.

**Thomas Willis, his life and work**

**Life**

Thomas Willis (Figure 4) was born on January 27, 1621, in Great Bedwyn, a large village in Wiltshire, about seventy miles west from London. At an early age he moved with his family to North Hinksey, across the Thames two miles from Oxford, where his father settled on an estate left by a famous namesake, Dr. Francis Willis, onetime president of St. John’s College in Oxford. Shortly after moving there, when Willis was ten years of age, his mother died. In 1636 Thomas Willis began his studies at Christ Church, one of the colleges of the University of Oxford, and in 1639 he took the degree of Bachelor of Arts. After three more years of lectures and disputations, Willis proceeded, on 18 June 1642, to the degree of Master of
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In his years at Christ Church college, Willis was thoroughly instructed in grammar, rhetoric, logic, politics, economics, and ethics. Greek and Latin were obviously the basis of all the instruction. His subsequent career might have been in the church, Willis probably intended to be ordained as an Anglican clergyman, but history intervened. In the summer of 1642 the English civil war between King Charles I and the Parliamentarians of Oliver Cromwell broke out. After a brief period of occupation by Parliamentary forces, when as an ardent Royalist Willis wisely left the city to avoid conscription, Charles I and his troops entered Oxford, which became the King’s capital throughout the war. The leisurely tempo of academic life was now shattered by the stir and bustle of an armed camp. In 1643 the overcrowded city and neighbouring villages were ravaged by ‘camp fever’. Willis studied and described this epidemic, with such care, that it forms an early statement of an epidemic of fever. His description clearly implicates typhus, arising from the epidemics in the troops of both sides of the conflict. Among the victims was Thomas Willis’ father who lost his life in June 1643, followed, ten days later, by Willis’ stepmother. Thomas was thus left at the age of twenty-one to maintain, as eldest son, his brothers and sisters. Willis, now the head of two families, moved back to his home at North Hinksey to manage the farms and to take care of the education of his younger siblings. However, Willis, always a staunch Royalist, returned in 1644 to Oxford to enlist in the King’s forces as ‘a Souldier in the University Legion’, an auxiliary regiment defending the King there during the siege of Oxford. Willis’ two years of military service probably involved short phases of intense activity, interspersed with prolonged periods of monotonous guard duties while living in grossly overcrowded conditions. When Oxford surrendered to the Parliamentarian forces in June 1646, all the Royalist soldiers were ordered to leave the city, and Willis probably returned to North Hinksey.

Willis’ attendance to his medical studies was quite exceptional for its brevity. He began his medical studies after he qualified Master of Arts in June 1642. However, during the years of the civil war in Oxford, all university instruction, including that of medicine was constantly disturbed. Willis formal medical training may have been as short as six months, and

Figure 4. Thomas Willis.
undoubtedly it was more of a literary study of medicine than a practical one. During his medical course he was probably influenced by William Harvey, who was then at Oxford as the King’s physician. William Harvey (1578-1657) studied medicine at the university of Padua. Harvey’s great contribution to medicine appeared in 1628 when his book *Exercitatio anatomica de motu cordis et sanguinis in animalibus* was published. In this landmark in the history of science, Harvey demonstrated the circulation of blood in animals, for good breaking with the old Galenic believe that the blood ebbed and flowed like a tide through the whole body. Six months after the war ended, Willis returned to Oxford, graduated Bachelor of Medicine and was licensed to practice on the 8th of December 1646 at the age of 25. Usually this degree would require three years of residential study after graduating Master of Arts, but during the civil war university regulations were not enforced, and the award of the degree, to a great extent, depended on the recommendation of Dr. Thomas Clayton, the Regius Professor of Medicine in Oxford. Clayton was a staunch Royalist and therefore he rewarded Willis for his loyal army service to the King.

Willis began his medical practice, as a qualified, albeit untrained, doctor in Oxford in 1647. He proceeded to establish a medical practice from his rooms in Christ Church, as would be possible for a doctor in Oxford with a medical degree, and a former student of the College. His patients at first would not be drawn from Oxford, as these would be cared for by established doctors in Oxford. What Willis did was customary for a novice medical practitioner. He visited the markets in the small towns around Oxford and stood there offering his services to the general public. The common practice among young struggling doctors was to prescribe treatment on the basis of examining the patients’ urine (the so-called piss prophets) and taking a history from the relatives. The convenience of this was that the urine specimen could be brought to the market by a relative or friend by whom the prescription or medicament could be sent back to the patient. Today this type of medical practice seems absurd. Urinanalysis was, however, the only form of clinical investigation in general use and was the precursor of today’s extensive clinical tests. Later Willis was to discover the difference between the polyuria of diabetes mellitus and that of chronic kidney disease. The sweetness of the urine in diabetics, enabling the doctor to distinguish this particular disease, from other causes of polyuria, was of fundamental importance, and this discovery had its foundations in Willis’ early experience at the markets. Qualified doctors such as Willis were competing with many practitioners, who had no recognised qualifications. These quacks prescribed not only medicines but charms and other magical procedures to cure ailments. Willis complained that a third of his patients had previously received treatment from these
unlicensed practitioners whose remedies he described as ‘a sword in a blind man’s hand’. Their remedies were indeed bizarre but so also were those of Willis. The difference was that Willis and his medical contemporaries were dedicated to a search for remedies with a rational basis and therein lay the seeds of the modern scientific study and treatment of disease.

Willis was fortunate in having the gifted William Petty (1623-1687) as his teacher in medicine and anatomy, for a few years after the Civil War. During the Civil War, William Petty studied medical subjects at Amsterdam and Utrecht, and in 1644 he graduated in medicine at Leiden where the course was more practical and better regulated than at Oxford. Petty had dissected for himself rather than watch others doing so; he had assisted at necropsies; he had prepared medicines; undertaken chemical experiments, and even examined patients at the bedside as well as reading about their illnesses. At Leiden there was also a tradition of private tuition and research. Anatomical dissections, chemical and physiological experiments were carried out in private houses, barns or the galleries in the botanic gardens. Willis and Petty were of the same age, became good friends, and spent much time together. On 14 December 1650, Willis and Petty became famous for a strange incident of resuscitation. The subject of their intervention was Anne Green, a 22-year old servant girl, who was seduced by her master’s grandson, became pregnant and gave birth to a child, probably stillborn, which she concealed. Her crime discovered, she appeared before the magistrate, was found guilty of murder, sentenced to death, and duly hanged on the gallows in Oxford. She hung for a half hour during which time her relatives swung on her legs and she was struck several violent blows in the stomach to speedily end her sufferings. Fearing the rope would break, the under-sheriff ordered the body to be cut down, placed in a coffin and removed to Petty’s lodgings for anatomical dissection. Petty arrived with Willis to carry out the dissection. The coffin had been opened and an onlooker, hearing the corpse breath, was trying, by stamping on her chest, to end her life. But when Petty and Willis arrived they ‘fell presently to act in order to her recovery’. They caused her to be held up in the coffin and then by wrenching open her teeth they poured in her mouth some hot cordial which caused her more coughing. They then rubbed and chafed her fingers, hands, arms, and feet, and, after a quarter of an hour of this with more cordial into her mouth and the tickling of her throat with a feather, she opened her eyes momentarily. At this stage the doctors opened a vein and bled her of five ounces of blood. They then continued administering the cordial and rubbing her arms and legs. Ligatures, presumably compressing bandages, were applied to her arms and legs. Heating plasters were put to her chest and another apparently inserted as an enema, ‘ordered an heating odoriferous Clyster to be cast up in her body, to give heat
and warmth to her bowels’. They then placed her in a warm bed with another woman to lie with her and keep her warm. Next day she was talking rationally, and after her full recovery Petty and Willis submitted on her behalf, a petition for mercy on the grounds that although her pregnancy had been the consequence of the ‘foule and feereful sin of fornication’, the foetus ‘was not only abortive or stillborne, but also so imperfect, that it is impossible it should have been otherwise’. After her pardon, Anne Green was exhibited in her coffin in order to provide for her future, in the room where she was to have been dissected. But when ‘multitudes flooded daily to see her’, the doctors arranged for ‘guards to control the crowd’ and they brought her father to collect the entrance fees. She eventually returned home with ‘the coffin wherein she lay, as a Trophy of her wonderful preservation’. She subsequently married, bore three children and enjoyed an unblemished reputation until her death in 1659. This unusual patient brought fame to Petty and Willis, which when Petty moved from Oxford and left medicine, devolved entirely on Willis, and materially helped his medical reputation. Willis also succeeded the gifted Petty as the leading medical scientist in Oxford.

By 1657 Willis’ medical practice and financial resources allowed him to marry Mary Fell, sister of Dr. John Fell, Dean of Christ Church, Vice-Chancellor, and promoter of the Oxford Press, who was a close friend of Willis. At the restoration of King Charles II in 1660, while Willis was still at Oxford, he was rewarded for his loyalty to the monarch by being appointed Sedleian Professor of Natural Philosophy. In the same year he was granted the degree of Doctor of Medicine. The importance of the Sedleian chair to the career of Willis was significant. This chair, established belatedly from provision in the will of Sir William Sedley in 1618, was intended to promote the study of Aristotle. The responsibilities of the chair included that the professor must read in full term, on Wednesdays and Saturdays at 8 am, from the books of Aristotle. The audience was composed of the bachelors of arts, who were fined 4 pence for non-attendance. Willis would have been fined 10 shillings if a lecture was not given. However, Willis soon started to incorporate his own theories and original data from his research into the lectures. Consequently his lectures were up to date and popular, attracting a far wider audience than the readings from Aristotle. Without the Sedleian chair, Willis would have been a successful physician, making discoveries in medicine and science, but possibly not sharing his findings and theories by publication. The diligent Willis constructed a series of lectures, which brought to his attention the imperfections of knowledge of his subjects. He then set about performing experiments and dissections to improve his knowledge, which he then incorporated into his lectures, and later published. In the same period he launched on the project which led to his book *Cerebri Anatome: cui accessit*
nervorum descriptio et usus, which was published in 1664 (Figure 5). Willis had some brilliant pupils or assistants, men who went on to successful careers. They included Robert Hooke, the great inventive physicist and microscopist; John Locke, the physician-philosopher who took lectures from Willis; Edmund King who, with Richard Lower, performed the first blood transfusion; and finally Thomas Millington and Christopher Wren, who were both directly concerned in the work of Cerebri Anatome. This intellectual set were some of the core of extraordinarily versatile scientists who eventually went on from Oxford to found the Royal Society in London. It is clear, particularly from Richard Lower’s letters that Willis exerted a considerable influence as a teacher on these keen young men. Willis’ position may be taken as that of a senior member of what we would call today a medical research team. Willis was one of the original fellows of the Royal Society of London for the Promotion of Natural Knowledge, being elected in November 1663. In 1664 he was made an honorary fellow of the Royal College of Physicians. The medical practice of Willis grew prodigiously and his income was now the highest of any person residing in Oxford.

Willis soon reached a plateau of work in the small city of Oxford. London, the capital, with the Royal College of Physicians, and the Royal Society, now had many excellent doctors and scientists, several from his own circle in Oxford and some of his own students. His move to London in 1667, precipitated by the invitation of his close friend Gilbert Sheldon,
Archbishop of Canterbury, was a natural extension of his career. He established his residence at St. Martin’s Lane. His practice in London soon became large and lucrative, and he continued to be an active and generous supporter of the established church. Both of his relatives who have written biographically of Willis emphasize that he also gave widely to charity. He became a celebrated physician in London and was indirectly involved in the care of Queen Catherine, who miscarried and was unable to bear children thereafter. However, Willis was also noted for his direct speaking, irrespective of the station of his patient. One hostile contemporary account puts it more directly, describing him as a ‘plain man, a man of no carriage, little discourse, complaisance or society’. When King Charles II, a noted procreator, consulted Willis regarding his wife’s infertility, he was not consulted again. In spite of being a Royal appointee, Willis’ bedside manner did not meet with Royal approval.

Success in his profession, however, was marred by domestic sorrows. Willis had four daughters and four sons, and all but the eldest son predeceased him. Willis’ wife died of tuberculosis in 1670. In 1672 Willis remarried Elizabeth Nicholas, daughter of the dean of St. Paul’s Cathedral. In his lifetime and posthumously, Willis’ reputation has been subjected to unsubstantiated attacks regarding his integrity. His contemporary attacks might well have driven by envy (he was the wealthiest doctor in Oxford). After a busy life devoted to the practice and teaching of medicine in Oxford, and later in London, he died of pneumonia on November 11, 1675, at the age of fifty-four. He was buried in the north transept of Westminster Abbey in London.

Work
Willis’ chief contributions were derived from his skill as an anatomist. He believed in first-hand observation and was quick to disregard the doctrine of others: “…I determined with myself seriously to enter presently upon a new cours, and to rely on one thing, not to pin my faith on the received Opinions of others, nor on the suspicions and guesses of my own mind, but for the future to believe Nature and ocular demonstrations…” Willis wrote on a formidable range of topics, including fermentation, fevers, urine, ascension of the blood, muscular motion, convulsive disease, scurvy, and the comparative anatomy of some dozen species ranging from the earthworm and lobster to sheep and man. He published numerous clinical and autopsy reports, particularly on neurological problems. Finally, in his last writings on rational therapeutics, he presented a vast and sometimes horrific pharmacopoeia in which, however, are buried useful descriptions of the anatomy of the blood vessels, the muscular layers of the stomach, and the detailed structure of the lungs.

His name has been associated with the syndrome of paracusis, the spinal accessory nerve,
the first division of the fifth nerve, the connective tissue septae in the dural sinuses, and, of course, the arterial circle at the base of the brain. The clinical observations of Willis include a description of the sweetness of diabetic urine and a lengthy discussion of various types of diabetes, known to his seventeenth-century patients by the quaint name of ‘chamber pot dropsy’ and ‘pissing evil’. He recorded epidemic typhoid fever among the troops in the civil war, described and named puerperal fever, gave useful descriptions of whooping cough and asthma, and pointed out that the intermittent pulse was not invariably associated with a bad prognosis. He contributed much to comparative anatomy. For example, he published the first detailed anatomical description of the edible oyster. Willis was also credited as the first to present the notion of a circulating hormone from the pituitary and from the gonads.

His extensive neurological writings still remain to be adequately appraised. His classification of the cranial nerves was in use for several centuries. He was probably the first to describe temporal lobe epilepsy and to report the effects of myasthenia gravis in a woman who temporarily lost her power of speech and became mute as a fish. He wrote on headache, epilepsy, apoplexy, paralysis of the insane, narcolepsy, and mental retardation. He explained hysteria not as a disorder of the uterus but as a nervous affection. The value of his observations on psychiatric disturbances has recently been emphasized.

Thomas Willis established the scientific foundations of the neurosciences, and in 1664, it was he in his book Cerebri Anatome, who coined the word ‘neurology’ to designate this body of knowledge. In his own words: “... in the mean time, our Method demands of us, that ... by the cense or numbering of the Nerves, ... we should deliver an exact Neurology or Doctrine of the Nerves ... although we know it is difficult to proceed with full Sail, we have resolved to undertake the task of the Doctrine of the Nerves: ... because without the perfect knowledge of the Nerves the Doctrine of the Brain and its Appendix would be left wholly lame and imperfect: ... without those things before known can the Pathology of the Brain and nervous stock be rightly instituted”. Cerebri Anatome is a unique document that ushered in the era of modern neuroanatomy and laid the groundwork for future functional neuroanatomic and neurophysiological investigations.

* Hetacombe refers to the habit of offering 100 animals on the big altar of Zeus on the fourth day of the ancient Olympic games in Greece.
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Literature