

# ON THOMAS WILLIS'S CONCEPTS OF NEUROPHYSIOLOGY

(PART II)

*by*

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## IV. THE PHYSIOLOGY OF REFLEX ACTION

During the present century, there have been a number of valuable reviews of the history of reflex physiology, from those of Fulton<sup>66</sup> and Fearing<sup>67</sup> to the more recent studies by Canguilhem<sup>68</sup> and Liddell<sup>69</sup> which, from different approaches, have clarified the historical problem. We are particularly indebted for guidance and information to Canguilhem's exhaustive account.

Although Descartes and Willis are now universally accepted as the pioneers of reflex physiology, it is of interest that Descartes was first mentioned by Arnold<sup>70</sup> and, apparently independently, by Du Bois Reymond,<sup>71</sup> while Willis's name was added even later by Eckhard<sup>72</sup> and Richet.<sup>73</sup> Foster<sup>74</sup> fully accepts Descartes's merit, while attributing to Willis merely a 'dim glimpse' of reflex action. Sherrington<sup>75</sup> pointed out that Descartes, in describing his automata, scarcely used the word reflex, while Willis gave numerous instances of automatic acts (which he named reflex actions) where stimulus was followed promptly by movement without conscious participation of the 'will'. His position, Sherrington continued, was a long way from that of Descartes whom—incidentally—Willis did not mention. In 1946 Sherrington wrote: 'The notion of reflex action is traceable to Descartes, but the term hardly. The term is traced more clearly to Thomas Willis.'<sup>76</sup> Sherrington's views have been confirmed and elaborated by Canguilhem who gives most of the relevant texts of both Descartes and Willis in Latin and in French translation.

Descartes<sup>77, 78, 79</sup> described and illustrated such reflexes as swallowing, flexion of arm and leg in response to strong thermic stimulation, pupillary accommodation reflex, palpebral reflex, coughing, sneezing, yawning, etc. Canguilhem claims, however, that he neither introduced the term nor—from the viewpoint of his physiology—could he have formed a concept approximating to that of modern reflex action. The animal spirits brought by the arteries to the ventricles (and the pineal gland) moved only centrifugally, viz. from the brain through the hollow tubes of the nerves into the muscles; centripetal movement was prevented by valves thought to be inserted in the nerve tubes. In the Cartesian scheme the centripetal part of a reflex arc would have been represented by fine fibres running in the nerve tubes and connecting the periphery with the pores on the ventricle walls: if an object falls on the peripheral sense organs, a pull is exerted on these threads which open the pores on the ventricle walls and thus admit the animal spirits for their centrifugal journey. This, Canguilhem claims, does not represent reflex action. In fact, the only time Descartes uses his term

'esprits réfléchis' (in *Les Passions*, article 36) is in the context of an action far more complex than a reflex. The merit of having introduced the word and the definition of a reflex action belongs, according to Canguilhem, to Thomas Willis. Whether one wholly accepts Canguilhem's logical analysis (which in his own confession is, perhaps, too subtle), there is no doubt in the mind of the present writers that the concept of reflex action of Descartes, who was primarily a philosopher, was far less physiological than that of Willis, who brought to it concrete personal experience in anatomy, physiology and in chemistry. The following brief quotation may illustrate this point:

'The sensory impulse arriving at the striatum not seldom, and without the hemisphere of the brain being affected, may, in a reciprocal tendency of the animal spirits, bend back and cause local motions; thus, during sleep, while the will is hardly conscious, we rub the place with our hand, where the pain is felt: more frequently, however, after the sensory impulse has traversed the sensorium commune towards the corpus callosum and has excited the imagination, the spirits will from there return (*reflexi*) and flow back towards the appendix of the brain, and, as its executors, provoke will and local motions . . .' (C.A. 54, A.B. 79). It will be seen that in this passage Willis described the scratch reflex which played such a large part in Sherrington's work.

Canguilhem lays great stress on Willis's use of the word 'reflex action' (*motus reflexus*). 'Or the *movement* of this and other kind is *reflected* . . . that is to say, in such a way that it depends directly on a previous sensation of obvious cause and occasion, and is immediately returned; thus, a light tickling of the skin provokes scratching of it, and the temperature of the praecordia intensifies pulse and respiration' (*De Motu Musculari*, 43; *Muscular Motion*, 28; our italics).

The one defect Descartes and Willis shared was that the brain was required to establish the connection between the sensory and the motor component of the reflex arc. The world had to wait another hundred years until Whytt<sup>80</sup> introduced the spinal cord for this purpose and thus prepared the way for Unzer,<sup>81</sup> Prochaska<sup>82</sup> and above all Marshall Hall<sup>83</sup> to build the modern concept of reflex action. Stirrings in this direction were noticeable, however, at the time of Willis. Leonardo da Vinci,<sup>84</sup> Boyle,<sup>85</sup> Redi,<sup>86</sup> Steno,<sup>87</sup> King,<sup>88</sup> and Swammerdam<sup>89</sup> had all observed that involuntary movements on stimulation could still be seen in decapitated animals. Willis himself had a clear notion that a centre other than the corpus striatum was involved in the arc of involuntary reflex movements:

'We have shown elsewhere that some nerves spring from the brain, and others from the cerebel; wherefore, when the former direct the impulse . . . immediately to the corpora striata, the latter convey the sensation from the fibres, which are planted somewhere more inwards about the viscera, to the cerebel; from which (without knowledge of the animal) oftentimes involuntary motions are retorted: as when vomiting follows upon an emetick medicine, unknown, and against our minds . . .' (D.A. 91, S.B. 61). In order to explain the related phenomenon of *sympathy* between different organs, Willis postulated peripheral communications, especially between the intercostal and vagal branches and vertebral (i.e. *spinal*) nerves: the latter, however, come in to establish rapport between voluntary and involuntary movement and not to form a link between the sensory and motor component of reflexes.

#### V. GENERAL DISCUSSION

If outstanding modern historians are at variance in their appraisal of Willis's achievements as much as Foster<sup>74</sup> and Mettler<sup>90</sup> on the one side, and

Neuburger<sup>91</sup> and Soury<sup>92</sup> on the other, there is bound to be a reason. To attempt an answer to this central question is the pivot around which we have tried to assemble the facts.

Willis lived at a time when, both in this country and abroad, scientists and philosophers of great stature abounded: Malpighi and Steno certainly surpassed Willis in the number of important anatomical discoveries. Willis's experimental undertakings bear no comparison with the ingenuity and fertility with which Hooke and Swammerdam carried out theirs. He made relatively little use of the microscope and seems not to have grasped its revolutionary potentialities which bore rich fruit in the hands of Malpighi, Hooke, Swammerdam, Grew and Leeuwenhoek. Even in iatrochemistry upon which, during his lifetime, apart from his undisputed fame as a physician, his reputation largely rested, he was (and is) regarded as second to Franciscus Sylvius. Willis did not fully grasp that, with Boyle, modern empirical chemistry had begun its stride (although he quoted the latter's experiments with air). This does not imply, as Boyle frankly acknowledged, that the iatrochemists did not continue to make important contributions to chemistry.

Regarding his relationship with the *Royal Society*, both Sprat<sup>93</sup> and Wallis<sup>94</sup> testify that at the early meetings at Oxford, Willis belonged to the inner circle of eight Fellows of the 'Great Club', who were described as the principals and the most consistently active in experimental research. Later, he seems to have attended seldom, and only once or twice is his name mentioned in Birch's *History of the Royal Society*<sup>95</sup> as making a contribution—in contrast to others such as Boyle, Wren, Hooke, Lower, Goddard, Croone, Charleton and King, many of whom were also physicians or surgeons. Although his name was on the list of 1660 (Birch, 1, 4), he was not elected until 18 November 1663 (Birch 1, 332), 'having been forgotten to be chosen at the time, when upon the renewal of the charter, the council, according to the power granted them therein, received and admitted into the society such persons, as had been elected Fellows before upon the first charter'. Curiously, his actual admission to the Society is not recorded before 24 October 1667 (Birch, 2, 201). The reason for this delay may be in the first place, that he possibly did not answer an inquiry 'whether he desired to be of the Society' (Birch, 1, 15) and secondly that his attendance was infrequent. He was never proposed to be a member of the Council. When he presented *Cerebri Anatome*, he did so through Bathurst, giving want of confidence as excuse for absence and for failing to describe himself on the title-page as a Fellow of the Society (Birch, 1, 444). When later, in 1667, his opinion was asked (by letter) on a powder for making artificial Spa water, he answered in writing, whereupon it was said: 'But the Doctor referring the Society to what he should make out when he should come himself, the consideration of this particular was deferred till that time' (Birch, 2, 225). One senses the impatience and annoyance of the Society at his lack of attendance. In fact, at the meeting of 19 December 1667, Willis made one of his rare recorded appearances.

The problem of arrears of subscriptions was one of constant concern to the Council. Birch reports that Willis was several times among the many Fellows

who were behind with their payments (e.g. among eighteen others on 22 October 1673 (Birch, 3, 95)). The only official notice taken of his death was a Council decision: 'that it be recommended to the care of Dr. King to solicit the executors of the late Dr. Willis for the payment of his arrears to the Society, amounting to twenty pounds and eleven shillings, as appeared from the Treasurer's book' (Birch, 3, 242). Again, it is difficult not to interpret this as a sign of distinct coolness, which is reinforced by the absence of an obituary note so regularly accorded to other Fellows. Hooke's<sup>96</sup> Diary does not mention Willis's death, although he records that on 11 November 1675 he dined with a party which included Oldenburg and King. This is in marked contrast to his notes on the deaths of John Wilkins, Goddard, Glisson, Mayow, Glanvill, etc. However, in the *Philosophical Transactions*,<sup>97</sup> on the occasion of a review of *Pharmaceutice Rationalis*, the death of 'This learned and Worthy Author' was 'reputed' as a 'publick loss, and a loss and detriment to the very Faculty of Physick'. Mention should also be made of the brief but moving tribute by R. Bathurst in the imprimatur to the Latin edition of Willis's last book.

On the other hand, laxity in attending may have been caused by conditions in the Society itself. Sir William Petty, in September 1674, complained of its lack of vigour and the dearth of 'entertaining experiments' (Birch, 3, 136), which he thought to be connected with the increasing arrears of subscriptions. Likewise, in 1686, William Molyneux wrote to the Secretary (Halley) as follows: 'There was a party arising in the Society that were for rejecting all kinds of useful knowledge except ranking and filing of shells, insects, fishes and birds etc. under their several species and classes; and this they termed Natural History, and Investigating Nature, never attending to the uses and properties of these things for the advantage of mankind' (Birch, 4, 475). This may well have reflected the opinion of others, particularly of busy physicians. It is not widely realized that this may have been one reason why Richard Lower, in earlier times a most active Fellow, fell behind with his subscriptions to the Society, so that, with four others, he was expelled in June 1675.

The cool relationship between Willis and the Royal Society (and vice versa) could be explained on grounds of differences in approach to science and of personality. Boyle, who at that time was, with Hooke, the dominating figure in the Royal Society, based the new experimental philosophy on the discriminating observation of facts and on their statement in a clear and simple style. 'They have exacted from all their members a close, naked easiness, bringing all things as near the mathematical plainness as they can; and preferring the language of artisans, countrymen and merchants, before that of wits and scholars.'<sup>98</sup> Willis, while he respected facts, believed that rational cogitation and hypotheses could fill gaps where facts were either not available or were controversial. Time and again he would say (as he did, for example, on cerebellar function): 'When some time past I diligently and seriously meditated on the office of the cerebel, and revolved in my mind several things concerning it, at length, from the analogy and frequent ratiocination, this (as I think) true and genuine use of it occurred . . .' (C.A. 74, A.B. 91). And when he spoke of 'by-ways or labyrinths, not before trodden', in prefaces to a number of his works, he was clearly thinking

not only of the discovery of new facts, but even more of novel theories. Boyle, who had energetically rejected his friend Thomas Hobbes's suggestion that experiment was a waste of time since the same result could be arrived at by pure cogitation, could not but view these tendencies of Willis's with the same misgivings.

Our knowledge of Willis's *personality* is rather scanty; it is based mainly upon reports by Aubrey,<sup>98</sup> Wood,<sup>99</sup> the postscript-obituary to *Pharmaceutice Rationalis*<sup>100</sup> written by his brother-in-law, John Fell, Dean of Christ Church and Bishop of Oxford, and the anonymous biography,<sup>101</sup> probably based on Morant and Willis's grandson Browne Willis—sources which may all have been biased either for or against Willis. Feindel<sup>102</sup> has given a summary of the known facts. Already as a child, Willis had shown signs of great sensitivity and generosity. On his way to school he would offer his food to the poor; when he went to Oxford, he intended to enter the Church. Although he gave up this idea, religion and the Church kept a great hold on him through his life. During the Commonwealth period, public prayers were held in his house—at no mean personal danger. Later in London he gave money for the 'Sacred offices of the Church to be celebrated daily early in the morning and late in the evening because he could not attend at Canonical hours'. Both his wives came from families of prominent churchmen. It was on the invitation of Dr. Gilbert Sheldon, Archbishop of Canterbury, to whom his main works were dedicated, that he moved to London. In his will provisions for the Church and the poor played the greatest part next to those of his family;<sup>103</sup> of medical men only John Masters was mentioned. John Fell describes him as an 'addict to the study of Piety' and Anthony Wood calls him 'an Orthodox, Pious and Charitable Physicean'. No doubt, this deep orthodox attachment to the Church contrasts with the sober 'rational theology' of Sydenham<sup>104</sup> and the practical Christianity of Boyle, who wrote 'For some Faculties and operations of the reasonable soul in man are . . . so peculiar and transcendent, that I have not yet found them solidly explicated by corporeal principles. . . . It will appear that incorporeal and intelligent being may work upon matter which would argue at least a possibility that there may be a spiritual Deity'<sup>105</sup> (*Works*, I, 450).

Although it is reported<sup>101</sup> that Willis's 'table was the resort of most of the great men in London', other evidence suggests that he had neither the time nor much inclination for social activities. Fell describes him as modest 'in the Highest Fame of Learning . . . sparing in his Speech . . . candid . . . frugal, denying all things to himself, yet denying nothing to the Poor and helpless. . . . In short, he was constantly exercised in Prayers, Studies, Labours, Alms and Watchings.' Wood also seems to allude to his lack of social and conversational skill, when he refers to him as 'a plain Man, a Man of no Carriage, little Discourse, Complaisance or Society'.

Willis's rare attendances may, to some extent, be explained by the severe stammer, mentioned by Aubrey. This may have induced him to avoid public, professional and social functions where it might be a handicap. In turn, the stammer may have had its root in his over-sensitivity and in a hidden lack of confidence which, for example, prevented him from presenting *Cerebri Anatome*

in person to the Royal Society. To whatever lack of confidence Willis may have been subjected, it did not prevent him from creating a position of inspiring authority towards his pupils, a most successful doctor-patient relationship and from becoming the head of the iatrochemical school called, according to Plot, 'The Willisians'.<sup>106</sup>

By contrast, the men who gathered around Boyle, Hooke and Wren were, on the whole, practical, realist, down-to-earth in their style, meeting and discussing their problems at informal dinner, coffee or drinking parties. They do not seem to have been frequent guests at the select dinner parties hinted at by the anonymous biographer. In Hooke's Diary, which in this regard is a valuable, though laconic and occasionally obscure source of information, we find a reference to Boyle or Wren almost on every page. There is no doubt that he mixed with physicians such as Sir George Ent, Sydenham,\* Glisson, Goddard and King more frequently and apparently more intimately than with Willis, a visit to whom he records only once on 12 June 1673, together with Sir John Hoskyns, who, in that year, was a member of the Council. It is quite possible that this visit was concerned with the arrears of subscriptions which at that time were discussed by the Council.†

Finally, there may have been a cloud over Willis's *scientific reputation* which perhaps accounts for the coolness of the Royal Society towards him. While his publications following *Cerebri Anatome* were received warmly in reviews of the *Philosophical Transactions*, no vote of thanks and—apart from *Pharmaceutice Rationalis*—no discussion is recorded in Birch's *History*. Severe criticism came from Steno<sup>109</sup> (1669, but verbally delivered in Paris some time earlier), who accused Willis (and Descartes) in the strongest terms of speculation about brain function. According to Neuburger, this 'philippic' had a shattering effect all over Europe.‡ We notice an echo in Schelhammer's *De Auditu*<sup>111</sup> (pp. 207 *et seq.*), when he includes Willis in the category of those who are

'unaware that similarities do not prove anything, unless it is previously known from other reasons, that what is alleged to be similar is similar; nor consider that similarity is merely an incentive for obtaining evidence which in science, and thus also in physiology alone has a place'; and he adds somewhat later (p. 210): 'For these reasons we cannot differ more from the opinion of this famous and, in Medicine, so well-merited man; although I admire his ingenuity whenever he explains the effect of medicaments or the causes of diseases, when he goes beyond his field, and takes on the role of philosopher, and ponders over the uses of organs or the nature of chemical events, I hardly ever desire his judgement nor would I have any confidence: for I have myself recently and publicly shown that the experimental results on which he relies are often different from reality.'

\* Sydenham, who was also a friend of Boyle and Locke, had close relations with this group, although he was neither a Fellow of the Royal Society nor of the Royal College of Physicians.

† It is unlikely that envy of his lucrative practice, though perhaps, as in the case of Sydenham, rife among Willis's practising colleagues, could have determined the attitude of the leading Fellows of the Royal Society. Nor is it likely that Willis's Royalist and Church attachment would have alienated him from this group of whom some held strong Puritan views (*vide* Finch's similar argument concerning Sir Thomas Browne<sup>107</sup>). Symonds's<sup>108</sup> tentative suggestion of the prejudice of the 'pure' physiologist against the clinician who interests himself in physiological problems is equally unlikely, as it would have applied to Lower, King, Charleton, Croone and others as well as to Willis.

‡ Steno's severe criticism may well have contributed to the bad reputation the word 'hypothesis' had in the seventeenth and eighteenth centuries.<sup>110</sup>

Nearer home, and probably before Steno, Charleton, in an unpublished manuscript\* bearing the date June 1664,<sup>113</sup> had raised criticisms against some of the localizations in Willis's *Cerebri Anatome*. This is his general conclusion:

'I remain in the same State of Uncertainty, concerning the Principal Seat of the Rational Soul in the Brain, and concerning her Oeconomy of which I complayned in the beginning, and which gave the first occasion to this Enquiry. For among all the Differences recited, meeting with no one, that seems to afford Significance enough to show me, *where* and by *what* immediate Instruments the Human Soul performs . . . those actions, which though Organical, and yet more perfect and Excellent than any actions of the Sensitive Souls of Brutes, or (to use Mr. Des Cartes' phrase) which depend upon her Conjunction with the body: I am very ? now—relapsing into my former despair of our being able to—comprehend *How far that Noble Essence is tyed to the Laws of Matter, and how far exempt from them.* . . . † These views were further developed in Charleton's *Different Wits of Man*,<sup>114</sup> but here were based exclusively on Vesalius, without quoting Willis.

An undercurrent of criticism because of the speculative nature of many of Willis's assertions has never died out completely. It is noticeable, for example, in Haller's<sup>115</sup> article on Willis. Hutchinson<sup>116</sup> agreed with Wood and Schelhammer that 'Willis hath founded a body of physic, chiefly on hypotheses of his own framing . . . but', he added, 'this foundation will not be lasting. Hence it is that, while his books show the greatest ingenuity and learning, very little knowledge is to be drawn from them. . . ; and perhaps no writings which are so admirably executed and prove such uncommon talents to have been in the writer, were ever so soon laid aside and neglected as the works of Willis.' Chalmers<sup>117</sup> and Munk<sup>118</sup> repeat the same criticisms which must also have influenced Foster.

This reproach of speculation was aggravated by doubts of Willis's originality in respect of *anatomical* discoveries. These doubts have been much discussed with regard to Lower and—to a lesser degree—to Millington and Wren, but they apply also to Willis's later work. In *De Anima* he was helped by Edmund King and John Masters, who also took part in the anatomical dissections for the first volume of *Pharmaceutice Rationalis* (1674), while King alone was involved in the second volume (1675). This collaboration was recognized at the time. ‡ As regards King's collaboration, Hooke, who in his Diary had not mentioned Willis's death, made, on page 203, the following entry on 24 December 1675: 'Saw Willis' new book and Dr. King's anatomical'; since no independent

\* We are indebted to the Librarian of the Royal Society for a photostat, and to the Council of the Society for their permission to quote from it. The manuscript shows the beautiful handwriting which, according to Moore,<sup>113</sup> Charleton preserved to the end of his days.

† Parts of words, especially in the right margin of the manuscript, are incomplete or illegible, but in most cases it was possible to ascertain their meaning.

‡ Stubbe<sup>119</sup> and Wood refer to Lower's help with the first edition of *Cerebri Anatome*, and it seems that Lower continued to make anatomical studies of the brain, for we find in a letter from Hooke to Boyle, dated 5 September 1667: 'I hope I shall prevail upon Dr. Lower . . . to get him anatomical curator to the Society. He has most incomparable discoveries by him on that subject, and a most dextrous hand in dissection. Some of his discoveries, I understand, will be published in the next edition of Dr. Willis's book "De Cerebro"' (Birch, 2, 206, fn.). In fact, no edition of the work containing material changes or additions was published in 1667 or later so that this intention does not seem to have been fulfilled.

It may be of interest that Burggrave<sup>120</sup> mentions a rumour that Lower had translated Willis's works into Latin. This is hard to believe if one compares the Latin style of Willis's publications with that of Lower in *De Cordis*.<sup>121</sup> The report indicates, however, how widespread rumours about the relationship between Willis and Lower were at the time.

publication by King of approximately this date is known, Hooke was probably referring to the second part of Willis's *Pharmaceutice Rationalis*, which had just been published. The Journal books of the Royal Society give some interesting information on the origin of work on lobsters and oysters. We learn that on 23 May 1667 'Sir George Ent mentioned that the anatomical committee had begun to make some experiments at his house upon lobsters and scates . . .' (Birch, 2, 176). All physicians belonged to this anatomical committee, though neither Willis nor King are mentioned specifically. On 18 March 1669 'Dr. King was put in mind of dissecting a lobster and an oyster' (Birch, 2, 356). Nothing further is heard of the matter until the publication of Chapter 3 in the first discourse of Willis's *De Anima*. We do not know of an independent publication by King on this subject.

Willis himself gave generous acknowledgement to the help he received from these men. His acknowledgement to Lower in the Preface to *Cerebri Anatome* is well known, but it is not always realized that his candid remark about Lower and the others who helped and 'instructed' him would be used against him by Wood and those who accepted the latter's views. In the Preface to *De Anima* Willis described the position as follows:

'The Anatomy of which being manifold and comparative,\* not being able to perform it only with my hand, and my own exertions being almost continually interrupted by my practice, the famous and skilful Anatomist and Physician Dr. Edmond King was much helpful to me, by his assiduous and notable assistance and labour. Also that learned Man, and my most intimate friend, Dr. John Masters, skilful in Physick and Anatomy. . . .'

One must infer from all this that the assistance given to Willis in anatomical work was substantial; this should not, however, be taken to imply that his part in dissection, observation and discovery was negligible. It is generally agreed that Willis was an accurate and original observer of clinical facts; there is no reason to believe that his gift for observation did not extend to other phenomena. Lower himself in his letters, written to Boyle between 1661 and 1663 (i.e. in the years of the preparation of *Cerebri Anatome*), has clearly shown how much he owed Willis.<sup>122</sup> These letters are worthy of fuller quotation as they indeed cast a new light on this old and vexing problem. On 15 January 1661 Lower wrote:

'I received your letter, and should have wrote to you sooner, but that the doctor (i.e. Willis) was not at leisure till of late to make those dissections of the brain, which he hoped: but at length we have had the opportunity of cutting up several, and the doctor, finding most parts of the brain imperfectly described, intends to make a whole new draught thereof . . . and only tell you that, according to his opinion of the use of the cerebellum for involuntary motion, he shewed me several times the nerves (which authors call the 6th conjugation) to proceed out of a stalk or stem, which comes down out of the cerebellum, and makes a great half circle under the medulla oblongata. . . .'

'Some of the dogs which we dissected after the butchers way, by cutting in two the spinal marrow in the neck . . . to see if the parts below the wound would retain any motion for a while . . . but the dogs never stirred any part below the wound . . . but the eyes moved and the eyelids. . . . I enquired of the doctor, what he thought of the nourishment of the liquor,

\* Pordage did not translate the word 'comparata', thus obscuring the important usage of the term 'comparative anatomy' by Willis.

which is thought to be in the nerves; and he told me. . . . He shewed me likewise the optic nerves plainly to ascend on each side of the bottom of the brain into those two parts on each side of the rima about the middle of the medullary substance of the brain, where he thinks imagination to be performed . . . ' (Boyle, R., *Works*, 6, 462–3).<sup>105</sup>

In a letter of 27 April 1663 Boyle (*op. cit.*, 6, 466) wrote: 'For I have been wholly diverted by Dr. Willis, whose desire it is, that I should be present at his operations, which now are very near finished . . . for the doctor intends, before Midsummer, to put his book into the press. . . . Dr. Willis presents you his service.'

Writing on 24 June 1664, he mentioned that 'Dr. Willis will send his book of the Diseases of the Head [obviously referring to *Pathologia Cerebri*] to the press this winter. . . . There is not a disease of the head which he does not excellently illustrate with very rare observations and cases . . .' (*op. cit.*, 6, 474).

When defending Willis against an attack on *De Febribus*, Lower<sup>123</sup> explained in his Preface that he did this though Willis did not need 'the assistance of any one, but entirely to ease him of the burthen of such a task, who was designed for nobler employments. . . . The learned Willis equally celebrated for his writings and gentleness of manners who neither by any word or acts had given offence to Meara. . . .' Franklin<sup>124</sup> reproduces an epitaph to Lower, dated from 1691 in which it is said 'When the learn'd Willis dy'd, he did impart His utmost Skill to thy capacious Heart. Full well he knew, *there* was no other Shrine so fit to keep his Treasure in.' This appears to confirm Symonds's<sup>108</sup> statement that the relationship between Lower and Willis remained harmonious to the end. It would be difficult to understand why King and Masters should have undertaken their later task, in the knowledge of an alleged theft from Lower. They probably all accepted that they received at least as much from Willis as they gave. This is how Stubbe<sup>119</sup> described the relationship. We quote from Franklin, who mentioned him before Dow<sup>125</sup> and Symonds: 'I think myself obliged to add one thing more where I speak as if Dr. Willis had had little to do in the discoveries of Dr. Lower about anatomy; that although that great Physicean had not leisure to attend the Anatomical Inquiries, yet did he propose new matter for improving the discoveries, and put Dr. Lower upon continual investigation, thereby to see if Nature and his Suppositions did accord; and although that many things did occur beyond his apprehension, yet was the grand occasion of that work, and in much the Author.' In the custom of our days, the assistance Willis received from others would have found an expression in joint authorship, and it is only fair not to forget this when quoting Willis.

With his customary candour Willis himself has revealed his relationship to anatomy in the conclusion to *Cerebri Anatome*:

' . . . for the crown of the work, a certain theory of the soul of brutes should be added after the naked anatomical observations and histories of living creatures and of their animated parts. Truly it is but just and equal, that we enter upon that other task of psychology and pathology so that the asperities and hard sense of our already instituted Anatomy may be sweetened with those somewhat more pleasant speculations, as it were cloathing the skeleton with flesh; and that the Reader being wearied by a long and troublesome journey, may be a little refreshed and recreated' (C.A. 176, A.B. 158).

This may have been meant as a comfort to the reader, but it is certainly not the language of a man primarily interested in anatomy, rather it is of one who regards anatomy as a necessary springboard for a rational understanding of nature, mind and disease. Willis was at heart a physician who turned to anatomy, physiology and chemistry in order better to understand and to cure disease.<sup>108</sup> That he was a great and devoted clinician and not only 'fashionable'<sup>74</sup> or a Dandy<sup>90</sup> is now generally accepted. Garrison classed him together with Sydenham, Heberden and Bright, for his remarkable 'capacity for close, careful

clinical observation'.<sup>126</sup> Vinchon and Vie have beautifully indicated his place in history:

'Willis nous arrête parce qu'il est à un tournant de la méthode dans les sciences. Il observe les faits avec précision, il pratique des autopsies, il expérimente sur des animaux vivants; et aussi, il raisonne, il induit, il déduit. Mais tout cela avec une confiance telle dans la démonstration que souvent il en choisit peu rigoureusement les termes; des analogies, des hypothèses tiennent lieu des faits; de là des conclusions trop hâtives.'<sup>127</sup>

Even Willis's admirers cannot deny his proclivity for speculation, so candidly admitted by himself, at the conclusion of *Cerebri Anatome*, and the cause of his condemnation by Steno to Foster. Canguilhem considers this harsh judgement too 'puritanical' and he is supported by Karl Popper,<sup>128, 129</sup> outstanding philosopher of science, for whom induction in the sense of Aristotle and Bacon, i.e. inference based on many observations, is a myth. The actual procedure of science, in his opinion, is to operate with conjectures: to jump to conclusions—often after one single observation. The true demarcation between scientific and pseudo-scientific statements lies in the refutability of the former, if they are subsequently tested against observation. Some of the most successful cosmological theories, from those of the Presocratics to that of Einstein were, when conceived, highly speculative and far removed from any observational basis.

The fact that Willis has been more acclaimed in France and Germany than in Britain and North America may have something to do with this. Not that scientific observations were any less accurate on the Continent, but physical and metaphysical theory was allowed to flower more freely than in the English-speaking countries.\*

Many of Willis's speculations have proved valueless. Others, for example, those concerned with the functional significance of the arterial circle, with the concept of the autonomic nervous system and its control, with reflex action, with normal function and pathology of the basal ganglia and of the internal capsule, all condemned as speculative, have proved to be fertile working hypotheses. If they were speculations, they bear, to use Keele's happy phrase, the 'stamp of genius'.<sup>131</sup>

Speculation differs in extent in Willis's publications. In *Cerebri Anatome*, accurate anatomical observation is, on the whole, well matched with imaginative interpretation. Perhaps this balanced approach in a book which also gave 'the most complete and accurate account of the nervous system to date',<sup>130</sup> contributed to its sustained success—'mira felicitas' as Soemmerring<sup>132</sup> called it; even today it still has its fascination. At its best—for example in the passages dealing with the function of the cerebellum, the description of the lower and higher reflex actions, etc.—it conveys impressive power to put observations into effective perspective. *De Morbis Convulsivis* also shows a balance between fact and theory, the facts here being mainly clinical. *De Anima*, although it contains, particularly in its second part, innumerable important observations, is perhaps more freely pervaded by repetitive and now valueless iatrochemical

\* Symonds<sup>130</sup> believes that in continental countries the Latin text was perused, while the English reader had to be content with Pordage's more ponderous and sometimes ambiguous translation. However, Foster, one of Willis's most severe critics, apparently employed his own translation of the Latin text. It may also be of significance that Willis's severest modern critics<sup>74, 90</sup> were anatomists and physiologists, whereas among his admirers one more often finds historians, clinicians, psychologists and philosophers.

and iatrophysical speculations. The same may be said about the two volumes of *Pharmaceutice Rationalis*. This assessment is in broad agreement with that of Symonds.<sup>130</sup>

Naturally, Willis had his predecessors: the distinction between voluntary and involuntary movement had been known since Aristotle and Galen; he derived the nervous connection between brain and heart from the 'little nerve' of Descartes (to whom he is also indebted for the 'organ' image); the creation of animal spirits in the cerebral and cerebellar cortex evolves from Franciscus Sylvius; the explosion theory from Gassendi and so forth. However, this does not make his writings wholly or even partially derivative. As Noyes<sup>133</sup> has shown in another context, Willis could share reproaches of this kind with Homer, Horace, Shakespeare, Newton and many others. True originality, in the arts as in the sciences, is shown according to Noyes, by the degree and the quality of development from the point where the predecessor ends. The present writers have little doubt that, in this sense, Willis possessed enough true originality to be considered not perhaps as *the*—as Feindel suggested—but certainly as *one* of the founders of neurology. He indeed introduced the term *νευρολογία* in the description of the nerves: preclinical teachers of our time still use the word in a similar fashion.

#### SUMMARY

An attempt has been made to explain the controversial judgement passed by modern historians upon the scientific achievements of Thomas Willis. It was found that both critics and admirers were right in essential aspects of their claims. As he himself confessed, Willis was not primarily interested in anatomy, and he probably received substantial assistance in anatomical work in the preparation not only of *Cerebri Anatome*, but also of *De Anima* and of the two volumes of *Pharmaceutice Rationalis*. However, having proved himself to be an accurate and original observer of clinical facts, there is no reason to doubt that his share in anatomical observation was equally substantial. In addition, he certainly provided the interpretative background, much of it speculative (as even Willis's admirers admit), but some of it, in the words of Anthony Wood, 'a lasting Foundation of a Body of Physic chiefly on Hypotheses of his own Framing'.

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