Form and Function in the Early Enlightenment

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Many physicians, anatomists and natural philosophers engaged in attempts to map the seat of the soul during the so-called Scientific Revolution of the European seventeenth century. The history of these efforts needs to be told in light of the puzzlement bred by today's strides in the neurological sciences. The accounts discussed here, most centrally by Nicolaus Steno, Claude Perrault and Thomas Willis, betray the acknowledgement that a gap remained between observable form, on the one hand, and motor and sensory functions, on the other. Observation yielded information about form, but did not guarantee a constant correlation with presumed function, while the mechanisms of sense and movement did not fit in with accounts of action and cognition whose purpose was to place the connection between active body and willful, conscious soul onto a descriptive rather than metaphysical plane. Teleology was now no longer a helpful tool in the disciplines of anatomy and physiology; the consequences of this are still with us.

Introduction

The birth of methods that allow for the "live" mapping of the functioning brain is probably one of the most remarkable landmarks in the rapidly developing technological landscape of our era. The concomitant possibility of mapping the *mind* by this means has not escaped the attention of neuroscientists, philosophers and the interested general public. One contemporary version of the old mind-body problem, in fact, addresses the issue of whether, by seeing the traces left by cerebral activity, one is understanding more about the products of this activity than ever was the case before, or inversely, whether the questions posed to us by this technology are not identical to those that were posed before the technology was born.

Attempts to map the seat of the soul are, after all, not new. During a

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previous era of rapid technological change, in the so-called Scientific Revolution of the seventeenth century, many physicians, anatomists and natural philosophers in England as well as France, Italy, Germany and Holland, engaged in the systematic study of the corporeal, or sensitive soul, that is, of the perceiving, sensing, emoting, cognizing mind. They provided their students and colleagues in academies and universities detailed descriptions of dissections they had either conducted, watched or read about. The history of these efforts needs to be told in light of the puzzlement bred by today's huge strides in the neurological sciences, for it can shed light on this puzzlement. Indeed, as will be recounted here, the interpretive lines along which early modern descriptions of brain functions were put down—whether outright materialist and thus novel at the time, or more safely mitigated in their interpretation of the modern, post-Aristotelian world that was emerging then—did not so much display an empirical theory of what the higher, conscious mind was, as trace the framework within which observation of its visible functions could be taken to make theoretical sense.

This article, then, explains how the maps of the soul produced by early modern naturalists, natural philosophers, physicians and anatomists turned out to suit their makers and the theories about the soul which they deemed most sensible, in an age in which God still mattered and in which theological constraints on materialism were internal to the very programs of the new scientific academies that, from the beginning of the early seventeenth century on, burgeoned all over Europe, from Italy to France and England. Intended as mirrors of what remained of the scholastic "corporeal" soul or set of functions taken to encapsulate both psyche and soma, the anatomical and analytical manuals bequeathed to us by the period's physicians did not actually make sense of the cleft between mind and body which Descartes had radicalized by the middle of the century. Instead, they provided an insight into the beliefs of the writers—themselves rational investigators of the "animal" aspect of human behavior. We shall see that acceptance of Cartesian physiology was limited among these clinicians, but that few of them questioned the prevalent methodologies of anatomical research, based as it was on functionalist assumptions.

It is a complex story, in which many thinkers and physicians of the period played a role; we shall meet a few of them in the following pages. The main focus, however, is on three of these figures, all of whom were central contributors to the development of natural philosophy in post-1660 Europe: the Danish anatomist, geologist and, later, converted bishop Nicolaus Steno; the established French, Académie des sciences architect, natural historian and theorist Claude Perrault; and the English, Royal Society physician, surgeon, anatomist and perhaps first modern theorist of

what we now call psychiatry, Thomas Willis. All three were profoundly aware of the difficulty inherent in determining what sort of relationship should prevail between observed form and visible, physical—anatomical or physiological—function, or between presumed form and invisible, especially cognitive function. The gradual breakdown of the teleological order guaranteed until then by the Aristotelian system meant that final causes were no longer useful tools for the natural philosopher; and the search for correlates between brain and cognition took place in a world where mechanistic laws were taking root alongside the humanist skepticism inseparable from the religious faith which sustained a commitment to the immortal, immaterial nature of the rational, superior soul of humans. The theoretical difficulties inherent in forging a properly "scientific" discourse on the nature of human cognition were thus far greater even than those bred by the absence at the time of technologies—such as MRIs—appropriate for the investigation of the human brain.

We thus begin with Steno—with his famed discourse, in part a response to Descartes which delineated the need to establish a new method for the study of the brain—before turning to Perrault's elaborate analysis of the use and limitations of functionalism in the study of the natural historical data gathered by his colleagues at the Académie des sciences, and to Willis's studies of the "corporeal" soul along Gassendist, rather than strictly Cartesian lines. We then analyze the issues raised by these and other, related texts within the context of questions concerning the putative material basis of the rational soul.[1]

I.

There reigned in France, in the medical fields, a confusion rather than a clear-cut opposition between traditionalists and modernists, conservatives and reformers or innovators, enemies or defenders of the theory of blood circulation.[2] To manifest a radical discontent with established anatomical beliefs did not signify alienation from the scientific or lettered community. On the contrary, someone like the Leiden-trained Danish anatomist, Niels Steensen, better known as Nicolaus Steno (1638–1687), a pupil of Sylvain de la Boé, was much admired by his contemporaries for the independence of mind and impeccable discipline with which he sought a new methodology for the precise execution and correct interpretation of dissections. He was interested in ensuring the plausibility of theories of physio-

1. This article was written before the publication of Robert Martensen, 2004, *The Brain Takes Shape: An Early History* (Oxford: Oxford University Press), which deals at length and in depth with many of the issues considered here.

2. Roger 1963 showed this extensively; see also Picon 1989, pp. 35–37.

logical function, whether his object of study was the heart or the brain.[3] He would be missed by his Parisian colleagues after he left the capital, where he had practiced dissections for a year or so, in the mid-sixties.[4] His posthumous influence on the general course of neuroanatomy was not as great as that of his contemporary, Thomas Willis (1621–1675), a star physician and anatomist on both sides of the Channel,[5] though Willis himself praised the Dane, and Steno's work on the heart would be taken up by other physicians of note, including, for example, Jean-Baptiste Denis, one of the first to perform a blood transfusion, in 1673.[6] What marks him out is his rejection of the use of systems as explanatory devices, too often abused, he thought, by anatomists who sought to cut corners; and he distinguished himself by basing his criticism of Descartes's notion that the pineal gland was the site for the soul's connection to the body on straightforwardly anatomical considerations.

Some time between November 1664 and February 1665,[7] Steno gave a lecture on the anatomy of the brain in Melchidésec Thevenot's Paris academy, one of the salons where natural philosophers and men of letters, including members of the Académie Montmor, met before Colbert instituted the Académie des Sciences in 1666.[8] It was published four years later, first in Latin, then in French, as the *Discours de Monsieur Stenon, sur L'Anatomie du Cerveau. A Messieurs de l'Assemblée, qui se fait chez Monsieur Thevenot.* The French edition was dedicated to Marin Cureau de la Chambre, physician to the king and, earlier, polemicizer in the period's ongoing debates about the nature of animal minds. Beginning with the declaration that he knew nothing about the brain ("Messieurs, Au lieu de vous promettre de contenter vostre curiosité, touchant l'Anatomie du Cerveau; je vous fais icy une confession sincere & publique, que je n'y connois rien"),[9] Steno made a solid case for the usefulness of deploying a

3. See Dewhurst, in Scherz 1968, pp. 43–48, at pp. 44–45. Steno was also active as a geologist; see, e.g., Scherz, ed. 1971.

4. See the review of Steno 1665 in the *Journal des Sçavans* 1665, pp. 139–142, at p. 141. Willis 1664 was reviewed in the same volume of the newly founded journal, pp. 16–19. See also Kardel 1994, pp. 1–57, and facsimile reprints of Steno's works on muscles, with translations, pp. 59–228.

5. The reviewer of Willis 1664 in the *Journal des Sçavans* 1665, p. 16, begins by describing the book as 'plein d'esprit, & remply de tant de nouvelles descouvertes'.

6. See Negri 1988, pp. 53–65, at p. 62.

7. See Schiller and Théodoridès, in Scherz, ed. 1968, pp. 155–170, at p. 159.

8. Melchidésec Thevenot (c. 1620–1692), traveller and aristocratic patron, was a friend and supporter of Steno, as well as of Jan Swammerdam, who was in Paris in 1664, and with whom he had a lengthy correspondence. He is the author of a *Recueil de voyages,* 1682 (Paris).

9. Steno 1669: 'Gentlemen, Instead of promising to satisfy your curiosity regarding the

common-sense skepticism in the pursuit of information about brain function. The brain, he wrote, was undoubtedly "the main organ of our soul, and the instrument with which it executes admirable things". But as he went on, in terms not unlike those used by Willis (and close, too, to those of the Epicurean and "libertin", materialist, headstrong physician Guillaume Lamy),[10] while this very soul of ours felt capable of knowing everything about the world, "when it returns to its own house, it is unable to describe it, and fails to know even itself".[11] Knowledge of the rational soul was therefore an epistemic problem, and not a moral or theological issue, nor a premise for faith. The moralist's deliberation, the preacher's sermon or the Cartesian theologian's universe were not of much help to the natural philosopher. Nicolas Malebranche, for one—Cartesian and main theorist of the doctrine of occasionalism—expressed the view that "Reason alone enlightens us about the fact that we are not a light onto ourselves".[12]

Steno was not happy about the "assurance" with which anatomists, seeking public admiration at the expense of good faith,[13] usually described the brain. It was, he wrote in terms that Lamy would use,[14] "as if they had been present at the composition of this marvelous machine, and as if they had penetrated all the designs of its great Architect".[15] They simply refused to acknowledge that methods of dissection were such that very little could actually be understood from the resulting observation of the brain;[16] and this was true whether one used the method of slicing the brain, unfolding it, or also separating grey from white matter.[17] Steno himself would have favored tracing the path of the nerves through the brain substance, but that was difficult to achieve.[18] His explicit pragmatism coexisted with a deeply held religiosity (he converted to Catholicism—in Münster, on 30 November 1651—and eventually became a bishop);[19] and

anatomy of the brain, I here make the sincere and public confession to you, that I know nothing about it.'

10. Lamy 1675, in Minerbi Belgrado, ed. 1996: 'Sixième Discours', and note 1, p. 95.

11. Steno 1669, p. 3. The book was reviewed in the *Philosophical Transactions of the Royal Society* 1669, pp. 1034–1037.

12. Malebranche 1674, in Rodis-Lewis 1962, IIIe Entretien, article X, p. 258.

13. Steno, *Discours,* p. 4.

14. Lamy 1675, 'Réflexions de Monsieur Lamy sur les objections qu'on luy a faites', p. 125.

15. Ibid., p. 2.

16. Ibid., pp. 38, 41.

17. Ibid., pp. 7–8, 22.

18. Ibid., p. 8.

19. See de Rosa, ed. 1986, p. 39, mentioning a letter from Steno to Malpighi, dated 24 Novembre 1671, in which Steno elaborates on the relationship between faith and scientific research; he refers, among others, to Spinoza and Dutch Cartesians.

he drew on a familiar natural theological argument when suggesting that those who believed that "the white substance [of the brain] is but a uniform body like wax, devoid of any hidden artifice"—like nerves—actually held "too low an opinion of nature's finest masterpiece. We are assured that wherever in the body there are fibres, they everywhere adopt a certain arrangement among themselves, created more or less according to the functions for which they are intended".[20] Yet, to admire a natural object for its complexity, and to see beauty in natural complexity, had little to do with the actual program Steno proposed. Unlike Robert Boyle—chemist, natural philosopher and co-founder of the Royal Society—who considered the mechanistic laws of the corpuscularian philosophy to be at once autonomous, specific to the natural (rather than the divine) realm, and a manifestation of what was a divine orchestration,[21] Steno set aside from his considerations any sense of divine order or law. In a way that might at first seem anti-theoretical, he focused instead on the pragmatic aspects of, and the real physical obstacles to, an effective anatomy of the brain. In this, too, he differed from Thomas Willis, in that he had no ambitions either for psychology—defined as the mapping out of the soul—or for psychiatry—understood as the aetiology of the soul's ailments.

Visible and analyzable as were grey matter, white matter, nerve extremities, and ventricles, it was easy, as Steno realized, to pass over errors of interpretation for the sake of offering to students and colleagues descriptions which fitted earlier, text-based presuppositions that, usually, had not been verified empirically.[22] So, for example, some considered brain ventricles to be the home of the spirits, while for others they were the receptacles of the brain's "excrement"; the spirits might originate in the vessels one could discern in the ventricles or, alternatively, in the brain itself. But no one, wrote Steno, was capable of telling exactly either from where they came, or where they exited.[23] Animal spirits might be the blood itself, or "a specific substance separated from the chyle in the glands of the mesenterium"; perhaps they came from the "serosities". According to some, they could be compared to "wine spirit"; but others "might wonder whether they are not the very stuff of light".[24] Accounts of brain function thus dif-

20. Steno 1669, p. 4. The translation is from Clarke and O'Malley 1968, p. 584. Clarke and O'Malley note that Willis took up Steno's suggestion to study the brain's white matter by following 'the nerve filaments through the substance of the brain to find out where they go and where they end'; there is an account of exactly such an experiment in Chapter IV of Willis 1683.

21. See Boyle 1686, ed. Michael Hunter and Edward Davis 1996 and editors' 'Introduction', p. x.

22. Steno 1669, pp. 33–34.

23. Ibid , pp. 5–6.

24. Ibid., pp. 6–7.

fered in the very details that constituted them; but there existed no solid basis for believing one thing rather than another, just as there was little basis for deriving with any certainty physiology and function, the "micro" realm, from anatomy, the "macro" realm. Moreover, there were plenty of divergences with regard to the actual significance one might attach to the variations in accounts of the relation of "macro" structures both to function and to the "micro" structures responsible for function. Steno was remarkably distrustful of theories of brain localization, both the ventricular one favored by the "ancients", and that of Willis himself, who, in assigning the common sense to the corpus striatum, the imagination to the corpus callosum and memory to the grey matter,[25] had advanced hypotheses which, in Steno's view, one would be hard put to confirm.[26] He observed that the striata were actually not discontinuous between grey and white matter, and that they even entered the spinal chord via the corpus callosum—itself "so unknown to us that with some imagination one can say anything one likes about it". It followed that there was no obvious reason for operations such as those described by Willis to actually happen in these bodies.[27]

The idea that the relation between form and function must be presumed unresolved precisely *because* form was hard to identify correctly is rarely found in other authors as explicitly as in Steno. Unsurprisingly, he thought well of Descartes's decision to describe the human body by resorting to a machine capable of performing human actions: it established function as the starting point of anatomical investigations,[28] and expressed a salutary modesty on Descartes's part with regard to the possibility of understanding the human body.[29] What disturbed Steno, precisely, was the abuse of this system by those who believed Descartes's automaton to be an exact replica of the living organism and a realistic depiction of the human body's "most hidden" elements, which it certainly was not, for Descartes, in spite of his extended practice of dissection, was no great anatomist.[30] On this basis, Steno could safely question Descartes's individual observations without undermining his systematizing philosophy as such. Steno patiently showed how a correct analysis of a correctly performed brain dissection proved that the pineal gland could not possibly function in the way Descartes imagined. Although it did adjoin the passage between the third and fourth ventricles, the pineal gland was not

25. Ibid., pp. 10–11. See Willis 1683, pp. 38–40.
26. See Clarke and O'Malley 1968, p. 159.
27. Steno 1669, pp. 11–12, at p. 12.
28. Ibid., p. 21.
29. Ibid., p. 13.
30. Ibid.; see also pp. 14 and 22.

placed within either the one or the other—contrary to what Descartes had assumed. To show this, it was only necessary to

> remove the cerebellum, or little brain, and one of the eminences of one of the tubercules of the third pair, or both of them if you want, without touching the ventricles; if you have done this carefully, you will see the posterior part of the gland, completely uncovered, and with no sign of a passage through which air or any sort of liquor could enter the ventricles.[31]

The reason why Descartes and even Willis were unable to make sense of dissections in this way was, of course, the intrinsic difficulty of observing the brain and of drawing it properly. Christopher Wren's—remarkable—figures for Willis's *Cerebri Anatome* were, thought Steno, "the best we have had until now", but even they contained errors, which Steno pointed out one by one.[32] A good dissection technique, drawing skills, and the interpreter's expert attention to detail were all necessary for a plausible account of brain anatomy and function. Results depended to a great extent on how one prepared the brain for analysis; and the names of structures were often based on the flawed interpretation of confusingly dissected brains.[33] As Steno rightly claimed, anatomists had always tended to be medical practitioners—doctors or surgeons—who could afford neither to allocate much time to pure research, nor to confess how little they knew of the subject, filling in the gaps with the texts of the ancients.[34] This was so in part because medicine was an art: to dirty one's hands would have been inappropriate.[35] If anatomists were not medical practitioners, they taught medical students—and, to paraphrase Steno here, their interest in anatomy was skin-deep.[36] Anatomy, in other words, and as Steno made clear, was a non-discipline. There had been all too few occasions or possibilities for any revision of established assumptions to occur.

Such a revision was nevertheless necessary. Anatomists had contented themselves with observing "movements" of the brain and constructing whole "systems" on the basis of these observations alone. They had been oblivious to the notion that "the same thing can be explained in a number of ways and that only the senses can assure us that the idea we have of it

31. Ibid., p. 17. The description continues until p. 21.

32. Ibid., pp. 23–26.

33. Ibid., pp. 22–31.

34. Ibid., pp. 34–38. See also Roger 1963, pp. 25–29.

35. Antoine Picon 1989 makes the point p. 36. One can also place this view of anatomy in the context of questions about variations in its epistemological status, from Hippocrates onward. Nancy Siraisi's account (1997) of Cardano's case is apposite, p. 103.

36. Steno 1669, pp. 34–35.

corresponds to what it is in nature".[37] The brain, Steno pointedly wrote, was a machine; and as with any machine, the only way to understand it was either to have its maker explain the "artifice"—that is, the functioning—of the whole, or to undo it piece by piece, and to examine each one in turn before looking at the way in which the pieces fit all together. One could not understand the whole without understanding the parts, he claimed.[38] Proper, empirical research could not even be methodical, because nothing about the brain's divisions and functions could be assumed *a priori.*[39] Steno insisted on this latter point, using his own knowledge and experience to back up his view that there was no use at all for mere "reasoning" in the pursuit of the understanding of anatomy, especially of such a malleable organ as the brain. Ancient anatomy could, of course, be of some help, but only indicatively;[40] too much reliance on it actually hindered the possibility of revision.

Steno was aware of, and precise about the ways in which the very process of dissection could distort the brain,[41] create parts and divisions between parts where they did not exist, and vice versa. He wanted to suggest a method which would define and delimit the impact of the experimenter as well as the role of ancient authorities, and thus ensure greater accuracy of observation, representation and interpretation. He proposed to "follow the laws of Philosophy, which teach us to look for truth while doubting its certainty, and never to content ourselves with it before the evidence of demonstration has confirmed it".[42] Exact figures were an important tool, especially for those whose aversion to blood, for example, meant that they never saw the dissected organ itself. For this reason, the absence of figures was preferable to the presence of false ones.[43] But there was no shortage of imperfect images of the brain, precisely because it always tended to collapse before one had managed to draw it properly.[44] Moreover, anatomists were all too keen to attribute a function to a part without even understanding its structure properly, replacing observation with the claim that "God and nature do nothing in vain".[45]

That belief in itself was not in question, in Steno or in anyone else who practiced anatomy at this level. But it did not provide any answers, either,

37. Ibid., p. 32.
38. Ibid., p. 53.
39. Ibid., p. 37.
40. Ibid., pp. 47–48.
41. Ibid., pp. 43–45.
42. Ibid., p. 49.
43. Ibid., p. 51.
44. Ibid., pp. 52–53.
45. Ibid., p. 53.

about what it was exactly that had been fabricated, by God or nature, with such a regard for ends. Nor did it say much about the best intellectual mechanisms and practical methods to employ for finding out how all natural structures cohered, as they were alleged to do. The only way forward, thought Steno, in a continuum with the methods established throughout the sixteenth century and culminating with Vesalius, was to go on practicing comparative anatomy.[46] As he wrote: "one should dissect as many heads as there are different species of animals, and different states [sic] within each species".[47] Brains "which have been changed by some illness" were also useful, since such changes indicated what it took for normal functioning to be possible, and what correlations there might be between abnormal behavior and anatomical or physiological incidents.

There was no doubt in the minds of those, like the architect, theorist and natural philosopher Claude Perrault (1613–1688), who practiced the dissection of animals and elaborated theories of the animal soul, that healthy organisms tended to behave in a goal-directed manner and that a mechanism had been put in place—by God or nature—to ensure the correct operation of the structure-function correlation. Organs were built in such a way that they were adapted to their functions. In a proposal which Perrault submitted in early 1667 for the anatomical program of the then newly founded Académie des Sciences, he made a clear distinction between truths "de fait", derived from the observation of the structure of dissected organs, and those "de droit", discovered through the experimentally and rationally acquired understanding of their function and action.[48] The nerves, for instance, were similar for each sense organ, but they differed in sensitivity and thus functioned appropriately to their respective roles, because their covering was specific to each one.[49] In this sense, teleology, or finalism,[50] was assumed to be explanatory of the mechanisms that made

46. For a study of Vesalius's use and applications of comparative anatomy, see Siraisi 1994, pp. 60–88: 61–62.

47. Steno 1669, p. 54.

48. Perrault 1667. Quoted and discussed by Picon 1989, pp. 44–46; he understands this distinction as one between anatomy and physiology.

49. Perrault 1680-III, p. 25.

50. I here take the term finalism, until Darwin the equivalent of teleology, in both the senses—distinct but closely related—identified by Minerbi Belgrado 1996 in the introductory essay to her edition of Lamy's anatomical writings, p. 12: on one, Aristotelian view, nature tends toward the realization of inbuilt ends, as if she were aware of them; on the other, Galenic view, nature is rather identifiable as a machine, operating according to mechanistic laws whose ends are intended only by the creator. By the second half of the seventeenth century, the first view was usually affirmed rhetorically rather than held in a literal sense, as Belgrado notes too; but it pointed to a general need to ensure a connection, in natural philosophy, between the pursuit of causal explanation and the precise identifica-

up living bodies; but the fact that an organ was present did not signify that its function was clear. Thus, espousing a version of the thesis that perceptual cognition was not bound to a specific sense, Perrault thought it best to posit the existence in insects of a universal sense, admittedly invisible, to explain their extraordinary perceptual capacities, for example the ability of ants to find sugar from a great distance.[51] In describing the ordinary, goal-oriented actions of living creatures, he accepted that final causes were inherently explanatory of such actions, but also maintained that actions which could be physically observed did not by themselves give an indication of what the correlated mechanisms at the "micro" level might be.[52] His postulation of a universal sense in insects such as flies and bees did not rest on the observation of an organ for it—whatever such a thing might look like. It relied instead on two assumptions: first, that goal-directed actions were essentially cognitive and in general could be accomplished thanks to perceptual mechanisms peculiar to the organism in question; second, that specialized organs had developed for the sake of these specific perceptual functions, but that we knew more about what the functions were than we did about how they actually worked.[53] As he wrote, we could understand how a telescope was made—that it consisted of a long blackened tube, lenses of various sizes and so on—and why it was made the way it was, given its intended function; yet, this did not mean that we knew why the lenses themselves functioned in the way that they did, what it was about the tubes that stopped light entering from the sides and so on.[54] In the same fashion, it was impossible "for us to discover what it is about the skin of the hand that makes it sensitive in one particular way, and the skin of the tongue in another way: because these organs do not function according to a composition known to us".[55] Between micro and macro there was an invisible link: we knew what the structural differences amounted to experientially, but we did not know what it was in the structure that resulted in such different sensations.

Empirical investigations into the character and function of sense organs thus went along with a belief in the importance of imagining biological structures not ordinarily visible to us, while accepting that these might be ordinary, natural, and necessary to physical life. At the same time, the pro-

tion of natural purposefulness. On the distinction between the two kinds of finalism, however, see also Roger 1963, pp. 74–79. On Aristotelian notions of teleology see Nussbaum 1978, pp. 59–106.

51. Perrault 1680-III, pp. 17–20.

52. Ibid., pp. 16–22.

53. See Des Chene 1996, p. 181.

54. Perrault 1680-III, p. 44.

55. Ibid.

cess of investigating the make-up of such structures did not so much wipe out any lingering intuition of finalism as help to flesh out a new use for it, one compatible with the all-important, and explicit, injection of skepticism into the Baconian process of scientific enquiry embraced by the Royal Society. All this was part of the continuing assessment of the role of rational deliberation in the new, empirical sciences of life. If the body of a telescope was related to its function in the way that the human body was to cognitive and perceptual processes, then establishing the grounds for a proper understanding of the latter—for a plausible way of deriving conclusions from observation—was bound to be a confusing process. Finalism helped to clarify the picture by ensuring a constancy in the structure-function relationship.

Still, the observation of anatomical structures was not close to shattering older assumptions about cognitive processes. No one could afford to question the division of the soul into, broadly, at least a cognitive—sensorial—and a rational part. Willis took up this dual theory, without, nonetheless, jumping whole-heartedly onto the Cartesian bandwagon, which, as we shall see, was not of direct use to physiological or anatomical work. A member of the Oxford group of Harveian experimentalists set up after the Civil War from which would grow the Royal Society, of which he became a Fellow, as well as a Fellow of the College of Physicians, a royalist and Sedleian Professor of Natural Philosophy at Oxford (notably to Wren, Lower and Locke, among others) Willis described his research as a way to "unlock the secret places of Mans Mind and to look into the living and breathing chapels of the Deity". This justified neurological enquiry in terms far less pragmatic than Steno employed, in response to those who regarded it "as a certain Mystery and Schoolhouse of Atheism".[56] Willis dedicated his *Cerebri Anatome*—which is still considered the foundational text of the anatomy and physiology of the nervous system—to his patron, Gilbert Sheldon, the Archbishop of Canterbury, proposing to look into nature as if he were looking into the Bible. The need to avoid a conflict between fact and revelation, in this instance, was prior to any questioning of the assumption that anatomical research was indeed a "Schoolhouse of Atheism". The onus here seemed to be on the prevention of conflict and the theological validation of his enterprise,[57] rather than on the establishment of a research method with which to set the practice of natural philosophy apart from any theological concern.[58] Such a concern, however, was

56. Willis, 'Dedication' 1684, p. 50. Cited by Dewhurst in Scherz, ed. 1968, p. 45.

57. See Johns 1998, p. 393.

58. Quoted from *Cerebri Anatome* by Scherz, in Dewhurst 1968, p. 51: 'These I desire, that all mine may be tryed and approved, no less by the demonstration of Piety and Canons of the Church, than by the Rule of Experience and Knowledge'.

embedded in the very adoption by Willis of a dualistic theory of mind, moderated by the Gassendist notion that the sensitive and rational souls were continuous with one another, according to a scheme described in great detail in the later *De anima brutorum,* or *The Soul of Brutes.*[59] Willis's ideas crossed the Channel quite speedily, thanks in part to Daniel Duncan (1649–1735), who published a work based on them in 1678.[60]

Willis combined the physician's expert anatomical sophistication with the fluent use of an interpretive apparatus that see-sawed between novelty and tradition, Galenism and Gassendist atomism, iatrochemistry and mechanism.[61] He developed a sophisticated physiology which derived authority from ancient sources and credibility from the application of up-to-date corpuscularianism to the atomist and Stoic theories of mind which filled the gap left by Cartesian dualism.[62] It was the very diversity of opinions about the soul, he wrote at the beginning of *The Soul of Brutes,* that showed "that she understands all things but her Self" and that the proliferation of new data about the bodies of animals and of man did not guarantee that such information was used to best effect. "Nevertheless", he went on,

> in this Age, most fruitful of Inventions, when that so many admirable things not before thought on, as it were another Ancient World unknown, are discovered, about the building of the Animal Body, when new Creeks are daily found out, new humours spring up, and altogether another Doctrine than what hath been delivered by the Ancients, concerning the use of many of the Parts, hath been instituted; why may we not also hope, that there may be yet another disquisition concerning the Soul, and with better luck than hitherto? Therefore, however the thing may be performed, I shall attempt to Philosophise concerning that Soul at least, which is Common to Brute Animals with Man.[63]

This was the "Corporeal Soul", "which seems to depend altogether on the Body, to be born and dye with it, to actuate all its Parts, to be extended thorow them", and the knowledge of which would ensure a better under-

59. On Gassendi's notion that the soul is a 'Certain Flame, or a Species of most thin fire' which is both 'Intelligent' and Artificial', and for Willis's comment that Gassendi never explains how such an 'inkindled and dilated' flame 'can be able to produce the Acts of the animal Faculty', see p. 4. The rest of the book is devoted to explaining these phenomena.

60. Duncan 1678.

61. For a good account of this, see Davis 1973.

62. See, e.g., Osler 1994, Osler 1986, pp. 163–183; Kargon 1964 pp. 184–192, in Chappell 1992, pp. 232–240. On Willis's preference, as a physician, for the chemical to the mechanical philosophy, see Wear 1989, pp. 294–320, at pp. 296–298.

63. Willis 1683, p. 1

standing of "the Ingenuity, Temperament, and Manners of every Man", including those "belonging rather to the Soul, than to the Body", such as madness and melancholy. An understanding of this corporeal soul would enable us to delimit its "bounds" and differentiate it from "the Rational Soul, Superior and Immaterial".[64] The immateriality of the rational soul was *proved* by the very impossibility of deducing its possible location from observation: the brains of humans and of dogs or sheep, say, did not differ greatly as to their structure.[65]

Willis thus applied comparative anatomy—as Steno had recommended, in line with predecessors from Vesalius back to Galen—to his investigation into the nature and operations of the all-important, complex corporeal soul, present in humans as well as in "brutes", as he made very clear from the outset. And crucially, he did not untie anatomy from physiology—the observation of form from the investigation of function—thus not effecting any real revision of the methodology used to arrive at an understanding of function. His analysis of the human nervous system was rather meant as a contribution to the idea that it was possible for an anatomist to find out *how* the corporeal soul operated, while also understanding ourselves as uniquely rational creatures, whose superior functions, because they were intrinsically immaterial and not physically manifest, remained outside the anatomist's field of investigation. We could see ourselves as a "two-soul"d Animal",[66] the "amphibian" creature Thomas Browne had earlier described in his *Religio Medici,*[67] which appears here bearing its theological and humanist pedigree—with Willis's reference, for example, to a gloss by "the most Learned Divine, our *Dr Hammond*" on St Paul's first "Letter to the Thessalonians" (5.23):[68]

> man is divided into three parts, to wit, First into the body, which is the Flesh and Members: Secondly, Into an Animal Life, which also being Animal and Sensitive, is common to Man with the Brutes;

64. Ibid.

65. Ibid., p. 44. See also Bynum 1973, pp. 445–458, esp. pp. 453–454, where he quotes the passage here and discusses its implications.

66. Willis 1683, p. 41: 'That Man is made, as it were an Amphibious Animal, or of a middle Nature and Order, between Angels and Brutes, and doth Communicate with both, with these by the Corporeal Soul, from the Vital Blood, and heap of Animal Spirits, and with those by an intelligent, immaterial, and immortal Soul'. See also Bynum 1973, pp. 449–450.

67. Browne 1642–1643, in Patrides, ed. 1977, I. 34, pp. 103–104.

68. Presumably Henry Hammond (1602–1660), a highly reputed divine, archdeacon of Chichester from 1643, made canon by Charles I, at Christ Church in Oxford in 1644/45, author of the successful *Practical Catechism* (London, 1644). See entry in *Dictionary of National Biography,* VII-VIII, pp. 1126–1130.

> And Thirdly, into Spirit, by which is signified the rational Soul, at first Created by God, which being also Immortal, returns to God. . . . Man is made, as it were an Amphibious Animal, or of a middle Nature and Order, between Angels and Brutes, and doth Communicate with both, with these by the Corporeal Soul, from the Vital Blood, and heap of Animal Spirits, and with those by an intelligent, immaterial, immortal Soul.[69]

It was "Reason" which persuaded us that the animal faculties could not be performed by the rational soul, "because the Acts and Passions of all the Senses, and Animal Motions are Corporeal, being divided and extended to various Parts; to the performing which the immediately, the incorporeal and indivisible Soul seems unable, so that it would be finite".[70] The scholastic belief that the sensitive soul was "subordinate" to the rational one had, for Willis, the consequence of turning the former into "a mere Quality"; and if one said that the latter bestowed "Life and Sensation, then Man doth not generate an animated Man, but only an inform Body, or a rude lump of Flesh".[71] The "Powers" of the rational, or "Superior Soul", meanwhile, were primarily discussed as that which humans use "expeditiously and freely"; they included "Intellect, Judgment, Discourse, and other Acts of Reason". The objects of the corporeal soul were merely "sensible things". Its "Knowing Faculty" was "Phantasie or Imagination"; that "of the human mind" was "every Ens, whether it be above, or sublunary, or below the Moon, Material or Immaterial, true or fictitious, real or Intentional". Though "degrees of Knowledge" such as "Apprehension, Enunciation, and Discourse" were common to both souls, the powers of the rational soul were, of course far superior to those of the corporeal one.[72]

Concerned with giving a convincing picture of the relationship between the two souls, Willis held on to the Galenic notion that animal spirits were instrumental in the operations of the corporeal soul, identified throughout as a "fiery" substance.[73] These were "procreated wholly", he believed, "in the Cortical or Barky substances of the Brain and Cerebel"; and they descended "by and by into the middle or marrowy parts, and there are kept in great plenty, for the business of the Superiour Soul".[74]

69. Willis 1683, pp. 40–41.

70. Ibid.

71. Ibid.

72. Ibid., p. 38.

73. Ibid.: Chapter II, pp. 4–7, is entitled 'That the Soul of the Brute is Corporeal and Fiery'.

74. Ibid., p. 24, and the whole of chapter IV: 'Of the Parts or Members of the Soul of the Brutes'.

This scheme allowed him to attribute to animals a "Council, or a certain Deliberation" and to reduce the "most Intricate Actions of Brutes, which seem to contain Ratiocination . . . into Competent notions of the sensitive soul".[75] In this way he bypassed the inextricable controversies which were inherent in a theological or ethical approach to the issue of animal cognition. Ethical soundness was here guaranteed by the conjecture that the rational soul was a substance which, "as it were presiding, beholds the images and impressions represented by the sensitive soul, as in a looking Glass, and according to the conceptions and notions drawn from thence, exercised the acts of reason, judgment and will". Animals did not need immaterial, immortal souls to have similar faculties; and their most "Intricate Actions", even those which seemed to entail some sort of rationality, "may be explained, and reduced into Competent notions of the sensitive Soul".[76] He compared the difference between man and animal to that between the musician and the tune. On the one hand, our rational soul "disposes and orders at its pleasure, the faculties of the inferiour soul"; on the other,

> the soul of the brute, being scarce moderatrix of its self, or of its faculties, institutes, for ends necessary for itself, many series of actions, but those (as it were tunes of harmony produced by a water organ, of another kind) regularly prescribed by a certain rule or law, and almost always determined to the same thing.[77]

II.

A powerful theory about the nature of organic, autonomous, generated animal life could thus be deployed on the basis of the analyzed function and status of physical organs—in those which were common to beast and to human. Willis tried to understand how the animal spirits—information carriers, in a sense—traveled within the organism, *given* the observed, and then carefully rendered structures of the brain. In this sense, the sorts of operations Willis depicted were more complex than those Descartes imagined from the hypothesis that the pineal gland was the seat of the rational soul. The corporeal soul "actuated" both "the Vital Liquor"—the blood, circulating in "Heart, Arteries, and Veins"—and the "Animal Liquor or Nervous Juyce", which flowed "within the Brain and its Appendixes".[78] It was "a certain fire or flame", he wrote. For Descartes, it must be noted, animal spirits, the smallest particles in the blood, had been, variously, "un

75. Ibid., p. 38.
76. Ibid.
77. Ibid., p. 34.
78. Ibid., p. 22.

certain air ou vent très subtil",[79] "un vent ou une flamme très subtile",[80] "un certain vent très subtil, ou plutôt une flamme très vive et très pure",[81] capable, on account of their small size, of reaching the brain and entering the pineal gland, which was inaccessible to larger particles. Willis's corporeal soul, on the other hand, lay "hid in the Blood, or Vital Liquour", and was spread throughout the body, exercising its faculties of motion and sense "in every one of the divided members". It had been shown that "Worms, Eels, and Vipers, being cut into pieces, move themselves for a time, and being pricked will wrinkle up themselves together".[82] Ignace-Gaston Pardies, author of an avowedly, but perhaps merely rhetorically anti-Cartesian tract on the nature of animal souls, used the data as well,[83] to show, in the first half of his book, that the material soul was diffused throughout the body.[84]

The Gassendist postulation of a corporeal soul allowed for a distinction between forms of knowledge rather more than did the mechanistic philosophy; indeed, Gassendism ensured that animals—as Pardies also believed—had no spiritual cognizance but were capable of a sense-based knowledge. Since animals showed evidence of memory, reason and so on, they must have a primitive, corporeal soul. In humans, the immortal, rational soul controlled the corporeal one, and the dissection of animal and human bodies yielded knowledge of the latter. Moreover, as Perrault himself wrote, the observation of animals—dead or alive—was eminently justifiable as a way of showing our "recognition" of the debt we owed to God for creating so many, and such diverse creatures, as our chief inheritance.[85] The ease with which it was possible to study beasts justified the natural philosopher's cataloguing endeavors, and the pursuit of observation and dissection.[86] Arguably, it was not the zoological curiosity underpinning such research that eventually came to reveal the mechanistic nature of animal function: on the contrary, curiosity was from the onset a key feature of our humanity, and of our difference from the animals we were so good at studying. With a nod to the "historical" method of surveying the "richness and variety"[87] of the animal kingdom, Perrault thus merrily

79. Descartes, *Les passions de l'âme,* Art. 7, in Alquié, ed. 1988, III, p. 957; see also Art. 10, pp. 958–959. See Pichot 1993, pp. 363–369.
80. Descartes, *L'homme,* in Alquié 1988, I, p. 399.
81. Ibid., p. 388.
82. Willis 1683, p. 5.
83. Pardies 1672, pp. 74–75.
84. Ibid., p. 69.
85. Perrault, , pp. 9–10.
86. Ibid., pp. 8–9.
87. Ibid., p. 13.

placed man alongside the foxes, swallows and worms, the flies and horses, bats and vipers, monkeys, grasshoppers and bears, together comprising a set classifiable according to modes of locomotion and nutrition, for example, but also according to the respective animal's main characteristics.[88]

Natural history was, in this sense, metaphysically uncomplicated. After all, the observation of anatomical form was an age-old practice, and the scientific curiosity which led to it needed no justification. In turn, however, it did lead to difficult questions about the causes, origins and functions of anatomical structures, reflected, for example, in the frequent combination of "rationalist" (Galenic) with empirical medical theory. Where the causes of symptoms could not be observed empirically, as someone like the physician Thomas Sydenham thought they should be, they had to be inferred; humoural theory, in such cases, had great explanatory power.[89] In the realm of anatomical and physiological, rather than medical enquiry, these difficulties with regard to the relationship of form to function were exactly what a treatise such as Perrault's *Méchanique des animaux* aimed to address. His goal, he wrote, was to

> explain through mechanism the main functions [i.e. movement, sensation and vegetative functions] of animals, by showing how nature gave each one, according to its species, different means of finding out, through their senses, what is good or bad for them; of going after or fleeing those things, through motion; and of staying alive through nutrition.[90]

And so, to the question that he himself posed, of *why* the sense of touch was different for each organ, and was harder to understand than were telescope lenses, he answered by positing a functional symmetry between, in this case, the machine's lenses and the eyes of a living creature: "what the lenses do in the telescope, the humours do in the eye", he wrote:

> The tube, blackened within, acts like the choroid, which is a black membrane built in such a way that it stops light from the sides; the diaphragm is pierced with a hole smaller in diameter than the tube, and has the same effect as the edge of the choroid, which makes up the pupil.

Even the capacity of the telescope to be lengthened or shortened according to the distance of the object under observation was similar to the way in

88. Ibid., pp. 11–13.
89. See Wear 1989, pp. 294–320.
90. Perrault 1680-III, p. 15.

which the eye's muscles, by contracting or relaxing, could set the distance between retina and crystalline, according to need.[91]

Mechanistic accounts of perception were useful because they were reductionist in form; furthermore, they integrated teleological principles and were self-justifying. Mechanical processes, wrote Perrault, consisted "of two things: either they facilitate the movement of bodies, or they delay it when needed". The perception of sound, for example, operated through both of these processes[92]—Perrault would devote the entire second volume of his *Essais de physique* to the matter of sound, enquiring into its nature, the modalities of its perception and the structure of the ear.[93] Similarly, the quality of vision in animals seemed to depend on how dark the environment of the eye was; and this in turn had something to do with the density of blood, itself a function of the amount and opacity of solid particles (of food and other substances) it harbored.[94] In instances such as this one, a mixture of corpuscularianism, iatrochemistry, mechanism and traditional Hippocratic-Galenic medicine helped derive theories of function from the observation of disparate features of anatomy and physiology. These features had to be read within a finalist framework, that is, within a picture of the body as an intelligently designed, organic entity whose every part must fit with the others—anatomizing the body in order to understand it made sense only insofar as it could be put together again. The same applied to the brain: the determination of brain function depended on assumptions about the material basis of cognition in such a way that finalism was intrinsic to the picture. This is why Steno's point that we had to acknowledge the depths of our ignorance about souls and brains before even thinking of moving forward was so remarkable. But Perrault, too, was aware that the very nature of the subject made many people reluctant to pay attention to scientific accounts of the "functions of the soul's sensitive powers"; as he saw it, these seemed available to introspection, and not really explainable on the same level as the objects of physics.[95]

The established, *a priori* starting position with regard to sense perception was that spirits became agitated upon the reception of nerve-mediated signals from external objects and communicated this agitation to the appropriate parts of the brain. There were variations on the theme, of course, according to the dominant school of thought. But the model, which measured its success in terms of a new kind of realism, was in itself

91. Ibid., p. 45.
92. Ibid., pp. 29–30; and p. 46.
93. Perrault 1680-II.
94. Perrault 1680-III, pp. 33–35.
95. Perrault 1680-II, p. 261.

the product of a complex, fragile mix, neither properly "modern" nor purely "ancient", at once fixed and evolving. Perrault accepted that, since "the soul is united with the body, it has its main seat in the most important parts". This meant that, lodged in the brain, the soul saw to

> the functions of the internal senses, because that part [the brain] is connected to all the organs of the external senses via the nerves, which ensure that the emotion caused in the organ by the objects is communicated to the brain, either through canals of sorts through which the light and mobile substance of the spirits transports this same emotion which the nerves received in the organs: or the very webs which make up the nerves, after having been agitated by the objects, cause a similar emotion in the brain.[96]

The relation between a cognitive event and a presumed, corresponding event at the "micro" level was here posited with graphic literalness. The anatomist was not searching for the spirits, just for proofs of their passage. These proofs could be found both in the mental and physical events they caused, and in the brain's well-analyzed anatomical structures. Again, they would not by themselves *establish* how the former and the latter were related. It was an—implicit—given from the outset that the relation between the two was on some level causal, and that analyzing the one shed light on the other. Perrault argued, on the basis of detailed observation, that the very ability of internal and external senses to respond to stimuli also meant that they could protect themselves against impacts that were excessively strong or inappropriate. Nature had "invented" means—"machines", as he put it—which ensured the right balance between the sensitivity of the sense organs and their safety.[97] To this was added the impressive way in which organs were specialized and built to execute their respective function. Sight and hearing remained separate from the other three senses in that their "objects are such that it is not necessary for their species to be united, because, since all the parts of the object are similar, it does not send different species, and each part of the species contains the entire species of the object".[98]

Sense objects were what they were, objects of the senses, specifically because the organs of sense were designed to modulate impacts from the outside through a modality each time adapted to both the object and the organ.[99] They were what made the world knowable, or, to put it in other

96. Ibid., pp. 262–263.

97. Perrault 1680-III, p. 43.

98. Ibid., p. 50.

99. Ibid., p. 46, where Perrault talks of 'the way in which organs of sight make its objects sensible'.

words, they were inherent in the world's knowability. The measure of the capacity of animals and humans to perceive their environment was, precisely, the structure of their sense organs. The very possibility of investigating sense organs and anatomical structures entailed the belief that an initial skepticism about the capacity of the senses to provide true information was not necessary for the establishment of epistemological certainty, as it had been for Descartes, and could only remain a theoretical premise. It was thus observation, rather than introspection, that undermined the use an anatomist might have for the exercise of Cartesian doubt. At the same time, the notion that living bodies were perfectly, divinely adapted to their environment was posited *a priori*—and therefore proven, rather than revealed, by observation. The very existence of the world and the uniformity and complexity of nature could be, to a convinced atomist like the physician, anatomist, physiologist and natural philosopher Walter Charleton for example, proof enough that they were a divine creation.[100] While the action of one body upon the other must necessarily be caused by "Mediate, or Immediate" contact,[101] the complexity of the atomistic universe quite simply entailed the lingering presence of the divine artificer. This is an instance and a source of the tension between a very modern, objectifying, "scientific" attention to biological detail on the one hand, and the continuing belief that such data, however extraordinary, must necessarily have their place within a divinely created natural order, on the other. The resort to mechanistic explanations of movement and perception fit very well within a definition of nature as perfectly regulated. Natural mechanisms remained safe even where the wonder of nature surprised; and so, however intolerable might seem Descartes's identification of beasts with automata, it did not really contradict the basic assumptions of those who rejected that conclusion but who were nevertheless inclined to refer to the bodies they studied as—admirable—"machines".[102]

It was very useful to believe in the—respectably seasoned—idea that to study the body, one had to understand it as a machine. Descartes had explicitly defined his automaton as a model. But those, like Willis, Duncan or Perrault, who actually identified nature with the best sort of artifice or machine, and God with the best architect, were in possession of a good alibi for their very real ignorance of how the body and brain functioned—as Steno had lucidly pointed out, though without rejecting the idea of the machine analogy. This alibi, by facilitating the validation and perpetuation of mechanistic accounts of the functions of the corporeal soul, would

100. See Kargon 1966, pp. xiii–xxv, at p. xx.
101. Charleton 1654, p. 343.
102. See, e.g., Giglioni 1995.

eventually be used in the case of functions—the exercise of reason and free-willed action—traditionally allocated to the rational soul and, up until then, considered mainly within the ambit of ethical or theological treatises, though associated, too, with the brain. In such cases, as we shall see, there emerged near-materialistic theories of the soul, for which it was acceptable to use *dispositional* accounts of intentional action without embracing Cartesian dualism in its pure state.[103]

Comprehension of how animal spirits traveled in the blood was bound to depend on an understanding of how the networking of veins and arteries was configured, given the direct correspondence between anatomical vision and physiological function. These animal spirits were usually explanatory of most functions of the corporeal soul; but their relation to the organs—such as veins, arteries and brains—in and through which they acted was far from clear. Willis had explained the function of the so-called arterial anastomosis, a circular group of arteries at the base of the brain, later named after him: it was in charge, as he established, of ensuring blood supply to the brain, and for long it had been confused with the *rete mirabile,* present, as it turned out, in all but human brains, and first described by Herophilus, before Galen integrated it into his physiology.[104] In Willis's time, though slightly earlier, it had been analyzed in further detail by the Swiss anatomist, physician and pharmacologist Johann Jakob Wepfer (1620–1695).[105] Close attention, after Harvey, to the circulatory system, helped make sense of the observable anatomy of cerebral structures and derive some grounded hypotheses about their physiological functions. And after Steno, the notion that the white matter was in fact replete with micro-structures helped Willis suggest precise trajectories for the animal spirits, and thus served as a direct basis for his theory of the relation between imagination, memory and common sense.[106]

Yet, while the notion prevailed that the body's motor and sensory activities must correspond to localized activities at the "micro" level, in specific parts of the body, and especially the brain, it did not help elucidate what an *explanation* of these activities of the corporeal soul might look like.

103. For Descartes and Cartesians, animal action was a function of the 'disposition' of organs. Midgley, 1979/1995, pp. 210–212, attacks Descartes's automaton thesis, his belief that the organs' disposition could suffice to explain action, and his reduction of animal action to organic disposition, arguing that reasons must precede causes in an account of intentional action. Reason might well be a universal tool, but, she writes, 'to have a universal tool is, of course, not the same thing as using it universally'.

104. See Clarke and Dewhurst 1972.

105. See Clarke and O'Malley 1968, pp. 769–779: pp. 775–779 for relevant sections from Willis 1664 and pp. 770–775 for selected passages from Wepfer 1658.

106. See Johns 1998, p. 395.

This is why Willis's insistence on ascribing specifically defined mental functions—those pertaining to the rational soul—to specific parts of the brain was upsetting to Steno. Willis, like him, had rejected the Cartesian notion that the rational soul was housed in the pineal gland, on the grounds that it was large in beasts, who were devoid of such a soul.[107] Yet, as we have seen, he simply transferred it elsewhere in the brain, associating its functions to those of the imagination, which in his view was located in the corpus callosum, as Steno had reported. Daniel Duncan gave different, but equally straightforward anatomical reasons for rejecting Descartes's thesis: the *septum lucidum,* he wrote, was delicate, and thus

> more susceptible to the motions that the nerves or spirits, once struck by objects, must impart to that part in which lies the soul; whereas the pineal gland, attached as it is to the extended marrow by a large number of vessels, is incapable of such motions.[108]

And he spoke of the "pineal gland, rotten and as big as a nut, that, in Montpellier, I saw being taken out of the head of a woman who had reasoned perfectly well until her death",[109] proof enough that the pineal gland had nothing at all to do with reason. The inference seems rather paradoxical—if the pineal gland had nothing to do with reason, then its physical state would not reveal anything about the state of a person's rational soul in the first place—but it illustrates vividly how the idea of associating a mental function with a physical location ended up highlighting the extent to which the actual functions one could attribute to the rational soul were ill-defined.

According to William Bynum, this resulted in part from Willis's functionalism with regard to anatomy: "the kind of structure/function analysis which Willis used", he writes, "could not accommodate (in the absence of unique neurologic structures) the qualitative physiological differences which he postulated to exist between men and animals",[110] since there were "no unique structures in the human brain in which the peculiar human capacities of language, reason, and moral judgment could be located".[111] There were few visible differences between human and other mammalian brains. The cerebellum, especially, was revealed by Willis's dissections to be relatively constant in form from one animal to the other, and from human to animal; he therefore thought that it probably corresponded to faculties which did not involve free will. The cerebrum varied

107. See Bynum 1973, p. 456.
108. Duncan 1678, pp. 26–27.
109. Ibid., p. 27.
110. Bynum 1973, p. 458.
111. Ibid., p. 453.

more and was thus more likely to be the seat of higher, human mental functions. But these functions turned out in Willis's system to be conditioned in part by the association of the cerebrum with imagination and memory, and thus dependent on the sensitive soul, which alone was amenable to anatomical observation and physiological analysis: "as to all its Powers and Exercises of them", he wrote, it was "truly within the Head, as well as in the nervous System, meerly Organical, and so extended, and after a manner Corporeal".[112] Man's rational functions, in this picture, had no clear allocation and were postulated rather than identified—they both separated man from beast and ensured a continuity between the two. The assumption remained, as Bynum has stressed, that the nervous system of humans, though close to that of many animals, was sufficiently different to suggest the existence of some physiological basis for the rational soul; and this assumption posed difficulties for the theologically necessary, but contradictory, hypothesis that the rational soul had no material basis. The criticism leveled from the very beginning at Descartes's dualism—that an immaterial soul could hardly have a material home and interact with the physical body—became the very source of difficulties for anatomists who sought to steer a commonsense course between dogmatic system and empirical method.

III.

Speculations about the functioning of living organisms thus relied on the Galenic notion that form and function were correlated. Man-made machines such as the one Descartes had imagined in his *Traité de l'homme* were characterized by a transparency of function. His automaton allowed Descartes to feel justified in relying on what seemed an exhaustive, mechanistic account of the artificial, "zombie"-like body in order to claim that our understanding of function could be entirely derived from both visible and invisible form.[113] Finalism with regard to structure was inherent within the mechanized, man-made automaton's body: it was precisely what drove its design. By contrast, living creatures, created by God, were not entirely transparent to the human gaze, and if they were necessarily perfect in design, this perfection could only be *ascribed* to them. The space left for the natural philosopher's speculations about the functioning of the body was thus as great as that filled by these mechanistic accounts, and, as we have seen so far, the one determined the shape of the other.

What one finds, then, in the accounts of dissections and of the corporeal

112. Willis 1683, p. 27.

113. See Gontier 1991, esp. pp. 6–8.

soul discussed here is a general acknowledgement that a gap remained between observable form, on the one hand, and motor and sensory functions, on the other. Observation yielded information about form, but did not guarantee a constant correlation with presumed function because no direct interpretation of visible organs was available. Senses and movements might be mechanizable, and partly explicable via chemistry, physics, and humoural theory. Yet, however identifiable, such mechanisms did not fit in with accounts of action and cognition whose purpose was to place the otherwise obvious connection between active body and willful, conscious soul onto a descriptive rather than metaphysical plane. The teleological subtext of the investigation of the body remained, in that anatomical structures continued to be understood *a priori* as the work of a divine designer. But teleology was no longer a helpful tool in the actual disciplines of anatomy and physiology. While the inherited, and deeply rooted, notion that function supervened on form would not simply vanish into thin air, the realization grew that there were no criteria—external to observation itself—with which to guarantee the truth-value of the attribution of sensory or motor function to organ.[114] It became clear to the physicians and experimentalists at the forefront of work in the new sciences that arguments from natural theology had rhetorical rather than explanatory value with regard to the natural creatures whose perfect anatomies they praised. It was fine to admire how functional, say, the eyes were. But that was not really the point of anatomy, which—according to a *Journal des Sçavans* reviewer of a "modern" medical treatise by one John Rogers—at its best might show what "actions happen inside our body" as much for the sake "of the propagation of the species as for the conservation of the individual".[115] Finalism played a minor part in the elucidation of what a specific organ was "for", simply because whatever connection existed between secondary and final causes had only a limited purchase on properly "scientific" activities—whether these partook of the mechanistic or the iatrochemical school, and whether one favored Gassendi over Descartes, or the other way round.[116]

Certainly, the eye continued to look for order in anatomized bodies—one which could be validated by testimony and reproduced two-

114. See Bynum 1973, pp. 445–447.

115. *Journal des Sçavans* 1665: review of *Analecta inauguralia, sive disceptationes medicae Doctoris Ioannis Rogersis* (London, 1664), pp. 65–66. Rogers adopted elements from Harvey, Glisson, Descartes and Regius in his explanation of the body's concocting activities, which included 'chylosis', 'chymosis', 'haematosis', 'pneumatosis', and 'spermatosis'.

116. For an analysis of the survival and role of final causes in the seventeenth century, and in particular in Gassendi, see Osler 1999, pp. 193–208.

dimensionally, or diagrammatically—where only the mess of tissue, organs and blood was discernible.[117] The living human body obeyed laws of physics, just like any other body. In the words of the (anti-Royalist) physician Thomas Sydenham, it "is so framed by Nature, that by reason of a continual flux of Particles, and the force of external things, it cannot always continue the same".[118] But faced with this constantly changing body—ageing, pregnant, ailing, gasping, sweating—its secretions and humours, animal spirits and sundry liquors, the hands-on physician could not have found much use in the automaton analogy, which, in the end, was as regular, clean and disembodied as were the criteria it was supposed to set for a new, scientific definition of life.[119] It was clear that "speculative theorems doe as little advantage the physick as food of men", as Sydenham put it, since "true knowledge grew first in the world by experience and rationall operations".[120] And indeed, once one had chosen to focus on the body's fluid contents rather than on its solid structure,[121] and on the "particles" responsible for bodily events and cognition, the notion of the automaton ceased to be of any use at all. To resort to an artificial model of cognitive processes, as did Descartes, in order to pave the way towards a new science of man, was exactly what the professedly skeptical natural philosopher could not afford to do: nature itself remained his realm of investigation.[122] To Sydenham, disease, for example, was "but a confused and disordered effort of Nature thrown down from her proper state, and defending herself in vain".[123] Descartes's model of mind, as we have seen, had been expressly designed as a solution to the skeptic's metaphysical doubt; but it was of no assistance to those who spent more time looking at the visible physical body, including the brain's structures, than speculating about the soul's invisible functions. Sydenham, a gout sufferer, knew all too well that a disease must be observed via the cataloguing of particu-

117. See Steno 1669, pp. 51–52. For a reliable outline of the history of anatomical illustration, see Roberts and Tomlinson 1992, p. 248, which shows convincingly that 'theories of use can impose an interpretation on anatomical structures'.

118. Sydenham 1696, 'Author's Preface'.

119. See Sawday 1995, p. 130, for a similar point about the inability of any model of the body, mechanical or Galenic, to be of use 'to a practical anatomist when he stood before a corpse, fresh from the gallows, surrounded by an expectant audience'. The body, quite simply, decomposed too quickly for the increasingly detailed investigations of anatomists to be carried out.

120. Sydenham 1669, in Dewhurst 1966, pp. 79–84, at p. 81.

121. See Dewhurst 1966, p. 74.

122. The automaton analogy, however, has its roots in the earlier 'homunculus', itself a product, from Aristotle onwards, of the relationship between 'art' and 'nature'. The fortune of the homunculus is well analysed in Newman 1999, pp. 321–345.

123. Quoted by Dewhurst 1966, p. 63.

lar symptoms; principles were of little help.[124] He condemned in "proud man" the inclination

> to penetrate into the hidden causes of things, lay downe principles and establish maximes to him self about the operations of nature, and then vainely expect that Nature, or in truth God him self, should proceede according to those laws his maximes had prescribed him.[125]

Moreover, while it was possible to stipulate that action, sensation and movement were correlated with thought and higher mental functions, a credible theory was needed with which to derive these functions—on an ocular basis alone—from a spatially extended organ like the brain. It would have to be an alternative to Cartesian mentalism, since, even on a functionally, let alone ontologically, dual picture of soul or self, introspective thought could not be the sole basis for knowledge of the physical dimension of movement, perception and general representations. A system such as the Cartesian one could, however, still be of use to anatomists to the extent that it provided both a metaphysical framework and an epistemological methodology for enquiry. In his "Eloge de Monsieur Tauvry", for example, Bernard le Bovier de Fontenelle (Secretary of the Académie des Sciences in Paris from 1697 until his death, aged one hundred, in 1757) praised the physician Tauvry (who had been inducted by Fontenelle into the Académie des Sciences before his untimely death, aged just over 31, in 1701) for the "great knowledge he had of Anatomy, to which was allied the talent to imagine successfully the use of structures; and in general he had a gift for system".[126]

Nevertheless, it remained true that the use of a metaphysical or methodological system in the processing of data yielded by observation-based experiment was much less attractive than the praise for the actual activity of investigating nature's profound complexities. Cartesianism was vulnerable to criticism precisely because it was a system.[127] Perrault preferred to combine systems, moderating the dogmas of mechanism while steering clear of what he considered the hypocritical professions of ignorance of those who, no less dogmatically, opposed the new philosophy.[128] Nature's

124. See Gunther 1925, 'Sydenham on Gout', p. 53.

125. Sydenham 1669, pp. 81–82.

126. Fontenelle 1708, p. 78.

127. This is explicit, for example, in the Jesuit Gabriel Daniel's stylishly ironic critique of Descartes 1691. Daniel was appointed by Louis XIV to write the history of France (the work, first published during the early eighteenth century, eventually comprised seventeen volumes).

128. Perrault 1680-III, pp. 3–4.

beauty consisted in its very diversity, he wrote, and just as a garden would not be more worthy of admiration for containing only roses, so

> the value of a variety of systems, some of which might be more probable than others, is higher than that of one sole, highly probable system; for there is no one system that is probable enough to resolve all the difficulties encountered in the course of investigating nature's secrets".[129]

What one system could not explain might be explained by another, he went on, which in turn might require the hypotheses of yet another, and so on, for "systems will succeed one another as long as the world lasts, and as long as considerations brought about by different phenomena generate new systems".[130] Perrault was well aware of the boundary within which hypotheses and theories were valid; but to him their circumscribed nature seems to have been a logical rather than a metaphysical fact. That theories were by nature incomplete did not have to hold back enquiry. On the contrary, it was only by acknowledging such incompleteness that enquiry could make any sense and that theories, indeed, could be made use of as theories at all.

On both sides of the Channel, the scientific academies of the post-1660s embodied a new, mid-way position between, on the one hand, Cartesianism or atomism, and, on the other, an avowed skepticism according to which nature's mechanical laws coexisted quite straightforwardly with the unaccounted mysteries of creation. At the purely pragmatic level of offering a viable explanation for puzzling biological facts—like the capacity of ants, to take Perrault's example again, of finding sugar from a great distance—the analysis of anatomical structures avowedly did little. At another, more general level, it remained a given that our epistemic relation to the natural world was not exhausted by our capacity to infer natural causes from observed natural phenomena. The great Dutch naturalist and physiologist Jan Swammerdam (1637–1680)—not himself a member of any of the French or English academies—wrote, in the conclusion to *The Book of Nature; Or, The History of Insects,* that:

> God's works are governed by the same rules; and as the true and primitive origins of them are infinitely beyond the reach of our comprehension, so that we cannot be said to know more than the bare outlines of that infinite Being's image, to whom they owe their existence; so I may hence, for certain, conclude, that all the knowl-

129. Ibid., p. 6.
130. Ibid.

> edge and wisdom of philosophers, consists merely in an accurate perception of these elegant appearances or effects, which are produced by first causes, and are often themselves, in their turn, the causes of other effects.[131]

The notion prevailed that the regularity of nature's laws and the infinite variety of its creations were manifestations of divine construction. There was also an infinite grandness to causality and the finite order of reasons, as well as a necessity for man's boundless ignorance of final causes. As an exponent of empiricism in the medical arts, Sydenham was, unsurprisingly, a firm defender of the notion that the scholastic love of totalizing systems bred ignorance.[132] The search for proximate mechanisms—within the realm of what we would term "life sciences"—could thus go along with the abandonment of natural theological arguments as useful tools for the immediate investigation of nature, causal processes and the order of reasons. This did not mean that the natural theological "tendency" disappeared, since mechanistic explanations themselves could point to God's greatness. To François de Salignac de la Mothe Fénelon, for example, "the whole of nature demonstrates the infinite art of its author. When I speak of an art, I mean the assemblage of means chosen on purpose for the accomplishment of a precise end". The universe most clearly must have been designed by "an infinitely powerful and industrious cause",[133] not by blind, necessary chance; and this idea of a divine architect of nature was, of course, widespread. But the reverse was not true: the investigation of nature and of the human body did not necessarily illustrate or bolster a finalist metaphysics. God had created the universe but secondary causes—the physician Daniel Sennert, a contemporary of J. B. Van Helmont, had already suggested as much in his *Hypomnemata physica* of 1636[134]—were not ruled directly by divine law. The study of movement, perception and cognition therefore had to rely explicitly on a dissociation of visible bodies from the higher, specifically human, immaterial, immortal soul. Compara-

131. Swammerdam 1758.

132. In what can easily be read as a plea against any form of 'dogmatic' knowledge, Sydenham 1669 wrote, p. 82: 'Whereas his [man's] narrow weake facultys could reach noe farther then the observation and memory of some few effects produced by visible and externall causes but in a way utterly out of the reach of his apprehension, it being perhaps noe absurdity to thinke that this great and curious fabrique of the world the workmanship of the almighty cannot be perfectly comprehended by any understanding but his that made it, man still affecting something of a deity laboured to make his imagination supply what his observation failed him'. See also Roger 1963, pp. 252–253.

133. Fénelon 1820, p. 5.

134. See discussion of Roger 1963, pp. 106–111.

tive anatomy—the cross-species studies of organs, which had already been invaluable to Harvey's work[135]—could be practiced precisely because it made sense to believe that nature was created in a unified way, by one creator.

But, as we have seen, comparative anatomy played an increasingly crucial role in the functional analysis of precise bodily structures. Dissections were highly fashionable in the Paris, London, Leiden and Florence of the latter half of the 1600s, though the minute observation of the natural realm was also considered by Cartesians like Fontenelle and Fénelon, as well as Robert Boyle[136] and the Puritan botanist, zoologist, geologist and anatomist John Ray,[137] to be something of a moral or religious, and consequently social or political, *duty.* It remained, though, that the knowledge yielded by empirical study was discrete, and only secondarily, if at all, systematizable. Looking at the dissected body did not in itself yield a fully agreed-on picture of how heart, lung, brain and muscle functioned, of what it was that flowed within the folds and parts of tissue that constituted them, or of what traveled within the nerves that seemed to connect those parts. As Walter Charleton put it, fellows of the London Royal College of Physicians, through their dissection practices,

> may come to know, what is perfectly naturall, what preternatural, what rare and monstrous among the parts of them; And also what resemblance there is betwixt the Conformation of the parts in the body of Man, and those in the bodies of other Animals, ordained by Nature to the same, or like and equivalent uses. So that it will be hard for any man to bring thither any Fish, Bird, or Insect, whose Entrails these genuine Sons of Democritus are not already intimately acquainted with.[138]

IV.

The acknowledged difficulty of inferring with any certainty the "micro" realm of physiology and function from the "macro" realm of anatomy was an instance of the changing status, role and procedures of anatomical observation, indeed of the observation of nature generally. It was also a mark—in the context of prevailing versions of "atomism" or "corpuscularianism"—of the absence of any definite or defining account of the exact nature of "atoms" and their equivalents. Surely, particles of various de-

135. On the issue discussed here see ibid., pp. 209–210, and Bynum 1973, p. 451.
136. See Mayr 1982, p. 313, and his quotation from Boyle.
137. Author of *Three Physico-Theological Discourses* (London, 1693).
138. Charleton 1657, pp. 34–35.

scriptions played certain roles, such as assuming the responsibility for the motion of all bodies and the sense perception of living organisms. But again, this was a postulate which did not actually bridge the gap between observation and theory.[139] Thomas Sprat, pointedly, would make clear in his manifesto for the Royal Society's program, the *History of the Royal Society,* that "the substantial" of its meetings "consists in *Directing, Judging, Conjecturing, Improving, Discoursing* upon *Experiments*".[140] As we saw earlier, it was only by positing hypotheses that experimental data could be assigned any coherent meaning. While it was quite obvious that the presence of a structure implied a correlated function, not everyone agreed that functions could be safely or reasonably presumed to exist where structures were invisible.[141] The answer to whether they did or not was bound to be theoretical rather than empirical. But this answer inevitably determined the sort of position one held with regard to the nature of the soul and of cognitive functions in living organisms other than humans, and therefore with regard to the very definition of life.

The move from the establishment of metaphysical foundations to anatomical modeling—and from the latter to the former—was riddled with conceptual difficulties. The body, once explained, could not reveal the secrets of the rational soul, packed with metaphysical baggage as the latter was. Nor was it ever assumed to do so, especially if one considered, as did Claude Perrault, that the soul which *could* be studied empirically was the very principle thanks to which animals, as well as humans, were capable of life.[142] What was assumed, and what the anatomist was supposed to reveal, was a direct, causal correlation between basic motor, perceptual, or cognitive acts (including memory) and animal spirits—material substances whose movements provided a medically usable explanation of action and emotion. This explanatory scheme, however, did not amount to a belief in the complete reducibility of such acts to matter. The higher, essentially immaterial, non-cognitive functions associated with the rational soul could not themselves correspond to the activity of the atomists' corpuscles. The human body stood between the visible and the invisible; and it was as such an equivocal object of investigation that it was studied. Perrault believed that it was easier to know animal bodies than the heav-

139. For an assessment of the sources and nature of early modern Democritean doctrine, see Lüthy 2000, pp. 443–479.

140. Sprat 1667, p. 95.

141. See Bynum 1973, p. 453.

142. Perrault 1680-III, 'Avertissement', p. 1.

ens, for they lent themselves to precise study more readily than the inanimate objects considered by the other sciences.[143] Indeed, as he wrote,

> the admirable functions of animals are produced by instruments we can see, whose workings are known to us by experiments which, being for the most part of a mechanistic kind, are not equivocal and uncertain as are all the other ones used to guess the causes and behaviours of other beings.[144]

But for him, it was definitely a soul, invisible to the gaze, which governed the movements of, and the relations between, the organs that made up the corporeal "machine" of both animals and humans.[145] This conception of the generically animal body as an admirable machine whose parts could be studied in detail suggests one reason why Galenic medicine survived ongoing developments in conceptions of the soul: it was a somatic theory that provoked no metaphysical uncertainties. Instead, relying on finalist assumptions with regard to the relation between function and structure in living organisms, it constituted a positive body of usable knowledge.[146]

The specifically "modern" practitioner of anatomy, meanwhile, poised as he was between old traditions and new trends, between metaphysical concerns and scientific empiricism, had to posit as unknown some relations between form and function. This was similar to the way in which optical devices, revealing new astronomical and botanical worlds, helped to re-conceptualize what lay between the seen and the unseen, the known and the unknown. Fontenelle described this very well in the *Entretiens sur la pluralité des mondes,*[147] and he would also write in the "Preface" to his *Histoire du renouvellement de l'Académie des Sciences,* at the turn of the century, that physics, "which studies an object of boundless variety and fertility, will always find something to observe and occasions to enrich itself, and it has the advantage of never being a complete science".[148] The body here came under the jurisdiction of physics (which could "rise to become a kind of theology").[149] The human soul did not; but naturalism was insidiously transforming it. Whether naturalism has transformed it irrevocably is a question we are still trying to resolve; and the answer may well never be final.

143. Ibid., p. 7.
144. Ibid., p. 8.
145. Ibid., p. 1.
146. The teleological tendency at its core was absent from the corpuscular, Epicurean school of biology. See Iliffe 1998, pp. 329–357, at p. 334.
147. First published in Paris, 1686. The book was a bestseller at the time.
148. Fontenelle 1708, 'Preface sur l'utilité'.

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