8
The puzzle of survival

> This *pneuma*-doctrine or spirits theory had retained its place in Western thought through into the seventeenth century. One might perhaps ask oneself: why?
>
> (Karl Rothschuh 1958: 2952)

> It is therefore necessary not to condemn Descartes if his account of the brain is not found entirely conformable to experience; the excellence of his genius, which appears particularly in the *Traité de l'homme*, covers the errors of his hypotheses.
>
> (Nicolaus Steno, *Discours sur l'anatomie de cerveau* (1669), in Brown 1968/1982)

Introduction

John Locke chose neural spirits as an example ('remarquable sur cela', added his French translator Coste) of the 'imperfection of words', of how 'doubtful and uncertain in their significations' many of them are (Locke, *Essay* III.9.1). He told of a 'Question, whether any Liquor passed through the Filaments of the Nerves', which had arisen 'by chance' at a meeting he once attended of 'very Learned and ingenious Physicians' (III.9.16).

The historical, plain Locke, aware that many words 'may serve for Civil, but not for Philosophical use' (*Essay*, heading to III.9.15), required his colleagues to establish 'what the word *Liquor* signified' before they continue their debate. The philosopher-narrator achieves his aim of proving the signification 'not so settled and certain, as they had all imagined', since 'each of them made it a sign of a different complex *Idea*'. But his own wry judgement that 'liquor' is not one 'of the most perplexed names of Substances' is vindicated, for, after Locke has kindly helped them clear away the verbal undergrowth obscuring their ideas, it turns out that the physicians 'differed very little in their Opinions, concerning some fluid and subtile Matter, passing through the Conduits of the Nerves; though it was not so easy to agree whether it was to be called *Liquor*, or no, a thing which when each considered, he thought it not worth the contending about' (*Essay* III.9.16).

Locke plays down ontological commitment in favour of linguistic purity: but his story confirms widespread belief in spirituous yet material nervous transmission. I described in chapter 7 Locke's own uses of the animal spirits theory of memory: here I return directly to the ontology of spirits and to the problems about theoretical change I set up in chapter 2. Why did philosophers and others believe that nimble spirits flow incessantly through those 'hydraulico-

pneumatical engines we call human bodies' (Robert Boyle, in Rather 1965: 3)? What should historians of science do with 'spirits no one had seen but which all were certain existed' (Rousseau 1991: 218)? How could such a fantastical theory have survived so long into the rational and empirical modern age?

The puzzle intensifies: how, we wonder, could Locke's medical contemporaries accept nervous fluids, when we find that William Harvey, renowned as the first great modern physiologist, was a mocking sceptic about the fleeting spirits?[1] As is well known, Harvey had sought to disprove the existence of spirit familiars and thus of witches by dissecting a toad. He complained that spirits are multiplied needlessly by bad philosophers. Animal spirits are brought, like gods in machines, on to the stage of the body, to unravel the plot and to bring the catastrophe (Harvey 1649/1990: 115–20). In fact, from at least as early as 1616, Harvey had believed there to be no neural spirits, good or bad, or causing diseases as the 'schoolmen' think: 'spirits' only exist in the blood (1649/1990: 118; Frank 1980: 1–16, 38–42). Historians of Harvey's work have often assumed that his attack must have been successful. We hear of 'Harvey's refutation of the spirits' (Temkin 1973: 158), or that 'the theory of *pneuma* lost its sense and relevance' (Brown 1968/1982: 46; compare Goodfield 1960: 18–20). But, as I have shown, the drama of the spirits continued long after Harvey's death, and only took more intricate turns with the new philosophies. Why?

Two puzzles

I divide the question into two more specific puzzles, about the survival of the spirits, and about their eventual disappearance. I complained in chapter 2 about historians' tendency simply to assume that the theoretical replacement of primitive spirits by more scientific concepts was inevitable. Such a view, I suggested, fails to explain when, why, or how theory-change occurred, and to account for the attractions of the tenacious spirits.

So the first puzzle, which I address in this chapter, concerns the spirits' survival in the face of apparent empirical refutation. The oddity has been noted before: Jackson (1970: 403) wondered why 'the continuing failure to demonstrate an actual [nerve] fluid only very gradually turned people away from the use of this term'. But no explanation is at hand. John Wright (1980: 246), puzzled that even empiricists employed and argued for animal spirits, suggests one possible answer: 'perhaps the real explanation of [spirits theory's] resilience to experimental refutation lay in the need, felt by the leading thinkers of this time, to assign psychological functions to physiological processes'. This sensible answer is also given by L.S. Jacyna in an important recent survey of 'animal spirits and eighteenth-century British medicine' (1995: 157–8). But,

1 For a full, nuanced account of the motivations behind Harvey's attacks on Renaissance theories of medical spirits, see Bono 1995: 85–122.

as both Wright and Jacyna are aware, it is far from enough.[2] Leading critics of animal spirits were not necessarily hostile to physiology, and nothing dictated that, of all possible physiological entities, animal spirits in particular should be the key.

Although I raise below some other possible answers to the puzzle of the spirits' survival, none is fully satisfactory. This means that wider neurophilosophical concerns about the spirits' role in preserving continuity of personal identity must be taken into account. The spirits had roles to play outside physiology, in debates about personal identity. In chapter 9 I show that their central place in accounts of moral control of one's own body, and in explaining tensions between physiology and morality, made them a ubiquitous theoretical foil in ongoing battles against confusion. The criteria for excellence of theory extended widely, well beyond the confines of what now look like 'internal' grounds.[3] Theory in physiology had practical and personal implications: knowing brain and body was a moral as well as a medical task.

The second puzzle, addressed in chapter 10 below, is this. Why did the eventual elimination of the spirits from neuroscientific ontology, from the 1740s on, occur *before* the advent of a clear alternative theory? This process was not an inevitable sloughing off of ancient neuromyths by scientists finally confident enough to jettison the venerable spirits before constructing a new, truly experimental theory of neural electricity. If this theory-change was indeed elimination, rather than reduction, its timing was due as much to changing moral and social ideals, the shifting normative expectations which neurophilosophy was meant to uphold, as to renewed attention to empirical doubts.

2 In his important survey, which I found too late for more extensive use in this book, Jacyna outlines a further candidate answer to the puzzle of survival. Like me, Jacyna thinks that the debate about nervous fluids 'did not . . . occur in a purely theoretical context' (1995: 149). He argues for the importance of practical medicine, suggesting that the traditions of talking about order, calm, and regularity in the spirits when diagnosing pathology and prescribing therapeutic remedies, made physicians comfortable in retaining spirits as theoretical entities (1995: 149–56): 'the doctrine of animal spirits readily accommodated key features of the system of "Bedside" medicine that was definitive of eighteenth-century practice' (1995: 158). There is no doubt about the importance to this problem of the social history of eighteenth-century medicine, and my brief remarks in chapter 9 about sensibility are, I think, compatible with Jacyna's suggestion. Yet neither of us has more than a hunch about what changes in medical practice might have contributed to the spirits' eventual elimination. In this short paper, Jacyna does not deal at all with the place of spirits in debates on the ontological status of hypothetical entities, or with the broader rhetorical roles of spirits in talk about the body and the self.

3 Reviewing the 'externalism/internalism' debate in the history of science, Shapin (1992) calls for attention to the boundaries constructed by historical actors between central, peripheral, and irrelevant concepts and issues. In this case, writers both for and against animal spirits threw the theoretical net wider than would later neurophysiologists; no clear line excluded moral implications from the justification conditions for physiological concepts.

Spirits: the case against

By the late seventeenth century, believers in spirits theory had a range of considerable obstacles to overcome. Despite its popularity, the theory of spirits and nervous fluids 'never enjoyed an unquestioned, unanimous support' (Pera 1992: 56). I examine a battery of objections to it, both logical and empirical. Some denied that nerves were hollow, as required for spirits to flow through; others complained that physical fluid spirits would be too inert to carry the commands of the will to the body's periphery as swiftly as action seems to follow from thought; a few experimentalists vainly sought indirect laboratory evidence for the spirits theory of muscular motion; and a number of natural philosophers questioned the theoretical need to postulate such problematic entities. I rely heavily on the work of modern historians of medicine to show that the many supporters of animal spirits must have had strong motivations for maintaining their beliefs (compare Jacyna 1995: 141–3 for another survey of challenges to the doctrine of spirits).

Hollow nerves

Despite their official invisibility, later seventeenth-century experimental neurophysiologists did embark on searches for the spirits. One strand was the search for nerve canals down which spirits were meant to flow (Flemyng 1751: 1–11). Antoni van Leeuwenhoek wrote to Oldenburg, in a letter published in the Royal Society's *Philosophical Transactions* of 1674, that he 'could find no hollowness' in the optic nerves of cows (in Brazier 1984: 35). But within a year he claimed to have seen 'a little pit' appear around the middle of the nerve, which pit, he imagines, 'Galen took for a cavity' (Brazier 1984: 35). By 1716, Leeuwenhoek claimed to have observed nerve canals 'often, and not without delight', but had 'been unable to display these cavities to anyone, for no sooner did I move them to my eyes for examination than almost immediately, in less than a minute, they dried out and contracted so that this astonishing sight wholely vanished beyond recall' (in Brazier 1984: 36).

This was received with some scepticism (E. Clarke 1968: 135–7), and most writers agreed with George Cheyne that the 'nervous Fluid has never been discovered in live animals by the Senses however assisted' (Cheyne 1705/1715: 306, in Yolton 1984b: 164). Doubts about hollow nerves led to doubts about their spirituous contents.

> How do you know that there are Animal Spirits at all? The Nerves, through which they are supposed to flow, are not hollow, made like Pipes, as Arteries, Veins, Lympheducts, Lacteals, and other Vessels, that are contriv'd to convey Liquids: They are solid Bodies like Strings, or Cords made up of many lesser Strings: No Liquid is found in them, nor have they any Cavity to contain it. Therefore this Business of the Animal Spirits is only a Dream. (Mandeville, *Treatise*, 3rd edn (1730), in Yolton 1984b: 168)

Disagreement over the hollowness of nerves became a popular feature of eighteenth-century neuroscience, as attention in general natural philosophy shifted from fluids to solids. But animal spirits did not stand or fall with hollow nerves alone. Solid-nerve theories did allow the application of forces by vibration, resonance, and impact without the use of fluids (chapter 10 below): but for Cheyne, for example, the solid-nerve hypothesis would alter our view not about the existence but simply about the nature of animal spirits. We would know them to be an 'infinitely subtle Spirit' which could pervade solid fibres 'with as much Facility as it would the most *pervious* Tubes' (Cheyne 1705/1715: 306, in Yolton 1984b: 164). Spirits could always be saved by turning them into even subtler matter. But in any case, as Clarke's survey shows (E. Clarke 1968: 137–9, 1978: 303), belief in hollow nerves survived far into the nineteenth century, well after animal spirits were either reduced or eliminated: so this could not have been a decisive objection.

The speed of thought

A second and related objection to the animal spirits theory of muscular motion was raised with increasing frequency during the eighteenth century. It started from the phenomenological absence of any temporal gap between willing and acting. Malcolm Flemyng, defending the nervous fluid, complained at the 'bugbear' of critics' harping on the celerity of the will (1751: 37). If I just decide to pick up my watch, the communication between soul and hand or centre and periphery seems to be almost instantaneous. How could particular spirit particles move from one end of a nerve to the other instantaneously if the nerves are fluid-filled? Even in cognitive activity, when the will wants something, its 'Volatile Messengers . . . are sent with unconceivable swiftness to penetrate every cranny of the Brain' (Mandeville 1711/1976: 158–9). Some thought that the vital messages of the will would not be carried to muscles or brain nooks fast enough, and calculated the velocity required of a nervous fluid (Brazier 1958: 206–7). It was, further, impossible to locate sensory and motor functions in the same hollow nerve, since fluids sent out from the brain would collide with spirits bringing news from the sensory periphery (Carlson and Simpson 1969: 103–4).

But these objections too were indecisive. Many were happy to separate sensory and motor neural functions. Flemyng grumbled that he had a right not to answer the objection from the metaphysics of the will, but went on to point out that the instantaneity of voluntary motion is only apparent, and that spirits theory did not require the *same* particular bit of fluid to travel all the way from brain to organ (1751: 26, 32, 34). Sound operates by waves, and the quickest voluntary motion is slower than sound (1751: 37). In 1783 Alexander Monro, whose father had, in 1729, listed objections to nervous fluids (Brazier 1958:

205–6), argued that the apparent inertness of neural spirits was no reason to deny that they serve 'the offices performed by the nerves'. His analogy was with the production of complexity from simplicity in reproductive physiology: 'the secretion and mixture of the fluids of the testes and ovaria' produces even more incomprehensible effects, so simple fluids in nerve ducts can give rise to flexible action (Monro 1783: 74–6).

Experiments in inflation

The inaccessibility of animal spirits to empirical investigation was not, however, universally accepted. Indeed there seems to have existed experimental evidence against them from the 1660s or 1670s (Mazzolini 1991: 81). English physiologists like Charleton had expressed doubts about the idea (common to Descartes and traditional spirits theorists) that muscular motion results from the inflation of a muscle by an influx of nervous fluid, and experiments in the late 1660s by Goddard and Glisson failed to find any increased volume in arm muscles on contraction (Brazier 1984: 55–9; Nayler 1993: 322–34). Glisson was sympathetic to a chemical interpretation of active spirits (Clericuzio 1994: 59–60), but developed an account of muscular motion, without reference to the spirits, which required nerves to learn the brain's commands directly (Henry 1987).

Jan Swammerdam, who had studied under Sylvius at Leiden and knew Cartesian physiology well, followed Descartes in interpreting 'the old animal spirit, passing from nerves into muscle, as a very subtle but material fluid' (Winsor 1976: 170). In an experiment which became classic only later, he tested the Cartesian idea that spirits flow into a muscle during contraction. While the enclosed nerve muscle on which Swammerdam stimulated contraction changed its shape, there was no increase in its volume. So whatever the 'supposed animal spirits' were that caused contraction, they do not inflate the muscle. Swammerdam claimed that 'no matter of sensible or comprehensible bulk flows through the nerves into the muscles' (Brazier 1984: 42–4 includes Swammerdam's illustration). The only possible empirical test for spirits resulted unambiguously in failure.

Against hypothetical constructs

Swammerdam's experimental critique supported a theoretical challenge to animal spirits by his intimate friend, the future bishop, Nicolaus Steno, who would discover the principle of superposition in geology (Gould 1983/1990). Steno questioned the excesses of Cartesian physiological speculation in a 1665 Paris lecture (Steno 1669/1965; Rome 1956; Brazier 1958: 204; Scherz 1965, 1976; Nayler 1993: 226–87). The ontological status of spirits is unclear, for nothing is known of similarities and differences between fluids in anatomically distinct parts of the body.

> Nor is it known whether any of these fluids are really like any one of the fluids so far known to us. Animal spirits, the more subtle part of the blood, the vapour of blood, and the juice of the nerves, these are names used by many, but they are mere words, meaning nothing. (In Brazier 1984: 50; compare Djørup 1968)

Steno sought a purer form of mechanism, purged of ambiguous spirits. His own theory of muscular motion, published in 1667, was geometrical in form and did not rely on uncertain inflation: good physiology would agree with Descartes in principle and Swammerdam in fact (Brown 1968/1982: 91–9; Kardel 1994a).

Descartes had defended the postulation of theoretical constructs in physiology by relying on analogies between the insensible parts of the body-machine and the larger parts of artificial machines. Parts which 'because of their smallness are invisible' can be made known through 'the movements which depend on them' (Descartes, *L'Homme*, AT xi.121, H 4, CSM 1.99). French Cartesians responded to general attacks on micromechanical speculation by emphasising the hypothetical nature of their claims (D. Clarke 1989: 152–6, 162–3, 186).[4] But the critics were *accepting* Descartes' terms, not simply rejecting the intelligibility of insensible entities. Swammerdam and Steno did not expect to be able to *see* the spirits, even with the aid of a microscope. Swammerdam looked for indirect confirmation of the theory in Cartesian fashion, seeking facts about small parts by examining the movements which allegedly depend on them, while Steno found no place for animal spirits in the range of existing sciences of fluids. Did these considerations not conclusively end the spirits' career?

Theoretical retention

Marielene Putscher, in an impressive survey of ancient and Renaissance theories of *spiritus* and *pneuma*, refers to 'the end of the *pneuma*-doctrine in the 17th century' (1973: 77, 94–6). Her list of relevant works includes only three books published between 1680 and 1700, and only three after 1700 (1973: 209–33). This might suggest the rejection of animal spirits in a new scientific age. But, as I have indicated, the impression is misleading, and is an artefact of Putscher's expertise in earlier periods rather than a reflection of the historical disappearance of the spirits. In fact, 'the doctrine of animal spirits did not succumb to the attacks made upon it' (Jacyna 1995: 143), and eighteenth-century physiologists, as other surveys make clear, were, if anything, even more occupied with problems about nervous fluids and spirits than their predecessors (Rothschuh

4 Rohault, in a textbook which remained influential among eighteenth-century Newtonians, agreed that Descartes' account of the formation of the spirits from blood involves untestable assumptions, postulating as it does 'yet another Sort of Matter not to be perceived by the Senses': but 'that there are such [spirits] cannot be doubted' (1723/1969: 271; compare D. Clarke 1989: 156). Thanks to Trevor McClaughlin for help here.

1958: 2963–8; Foucault 1972: 226–316, (trans. 1965: 85–158); Rousseau 1976, 1989). The century's most celebrated physiologists, Boerhaave and von Haller, strongly defended nervous fluids, Haller undertaking an extensive history of the doctrine before arguing for the existence of spirits as mobile, subtle, and invisible rapidly flowing fluids (Hoff 1936: 163–8; Lindeboom 1974; Pera 1992: 55–9). The *Encyclopédie* article '*nerf*', by Jaucourt, retained nervous juices in preference to vibrations (Starobinski 1966: 177–80). William Cullen's physiology, towards the end of the eighteenth century, was based more on solids, but still retained a central role for neural fluid (Riese 1959: 52–8; Jackson 1986: 124–8; Wright 1990: 292–301).

So despite all complaints about the unsuitability of spirits, and despite various alternative forces, vibrations, and ethers, the spirits hung on in. Why? Marcello Pera (1992: 56) complains that the defence of spirits in both Boerhaave and Haller is obviously unsatisfactory, 'regressive reasoning' which seeks to establish the properties of spirits on the assumption that some such fluid must exist: their 'regressive method . . . took as its starting point the very phenomena it should have explained'. If Swammerdam's experiments 'refuted' and 'destroyed' theories of nervous fluids (Singer and Underwood 1962: 134, 140), why do we find rational physiologists continuing to succumb to the seductions of the spirits?

It is not, as I initially thought, that the attacks failed to reach their audience.[5] Swammerdam's experiment was only published by Boerhaave in the 1730s and translated into English in 1758, and the dissemination of his ideas is hard to trace (Schulte 1968). But it seems likely that Locke, for instance, was aware of his work: Locke owned four of Swammerdam's published works (as well as four of Steno's), was a member of the Amsterdam College to which Swammerdam had belonged, and visited Swammerdam's museum in 1684, four years after Swammerdam's death (Harrison and Laslett 1971: 239, 242; Colie 1960/1990; Rupp 1990: 276; Dewhurst 1963).[6] Steno was active in European physiological correspondence: his research was praised by Oldenburg in the Royal Society *Philosophical Transactions* of the late 1660s, and Hooke as curator of experiments was asked to replicate some of Steno's methods (Brown 1968/1982: 104–21). The September 1669 *Transactions* recommends Steno's *Discours sur l'anatomie de cerveau*, the newly published version of his 1665 attack on Descartes' nerve fluids (Rome 1956: 260–1). Borelli tried to

5 Although Franklin Fearing (1929: 384) was unfair in complaining that (in addition to 'an anatomy the details of which were largely imaginary') Descartes's 'major error' in retaining animal spirits was due to his 'ignorance of the work of his contemporary [sic], the Dutch naturalist, Jan Swammerdam'. Swammerdam was born in 1637, only thirteen years before Descartes' death.

6 In 1686, Locke did meet Leeuwenhoek, who showed him 'some red blood cells, a human tooth, and the spermatozoa of a dog' (in Dewhurst 1963: 229).

bypass the negative results of the inflation experiments with new geometrical models in which inflation occurs only within a complex structure of massed chains of rhombs in muscle fibre:[7] so when Steno visited Italy in 1666–7, his disagreements over nervous spirits with Borelli and Bellini were eagerly followed. William Croone had met Steno in Montpellier in 1665, and they corresponded: Steno's 1667 work on muscular motion halted Croone's revision of his own 1664 book (Rome 1956: 245–53; Wilson 1961: 164–5; Kardel 1994a: 23–37).[8] Hooke addressed Steno's work in both geology and muscle physiology (Brown 1971). So English as well as Continental theorists, it seems, should have been further swayed by the critics.[9]

The invisible world

An answer about the puzzle of spirits' survival can start with two thoughts about the Swammerdam/Steno critique, to do with observability and with explanatory ambition. Firstly, Swammerdam himself did not interpret his own experiments as proving that there are no animal spirits: instead he argued that, if matter does flow through the nerves, it must be *completely* insensible, its effects below the threshold of measurement (Winsor 1976: 170). Neither experiment nor the new microscopy could resolve decisively the ontological issue (Brazier 1958: 202). Nayler concludes her vast analysis of theories of muscular motion by denying the possibility of a crucial experiment on the inflation hypothesis and the existence of animal spirits (1993: 579); Kardel (1994a: 47–57) believes that only new computer-modelling techniques allow full appreciation of Steno's detailed theories.

The problem was not just that spirits dissipate on removal from the living nerve, or that Hooke's advice in Observation 43 of *Micrographia* to avoid putting Nature into disorder by experimental violence, and instead to 'quietly peep in at the window, without frighting her out of her usual byas' ('Espinasse 1956: 58; Guerrini 1989) could hardly be applied to animal spirits. It was still open to corpuscularian spirits theorists to argue that the wonderful invisible world

7 Borelli had been disappointed at *L'Homme* on its publication in 1662, considering that he had already taken mechanistic physiology further than Descartes by attempting geometrical models which would aid quantification (Brown 1968/1982: 82–91).

8 Wilson (1961: 164) claims that Croone 'altered the concepts of spirit from that of a vague and ethereal wind to that of a definite physical juice and thereby made them susceptible to observation and reason': however, there does not seem to be any evidence that Croone became the only person ever to see animal spirits.

9 An early response to Steno was John Mayow's attempt to render animal spirits static, and attribute the turbulence which causes physiological and psychological disorder instead to other bodily substances. Responding to Steno's denial of inflation, Mayow argued that animal spirits never change, but that they are affected by the volatile 'nitro-aerial spirit' which can 'penetrate deep into the brain and perturb the animal spirits' (Mayow 1674/1957: 233, 251, 280). Mayow renders animal spirits so 'ethereal' that he rules out a theory of memory, for they are 'so slender that they are at once dissipated and leave no vestige of themselves' (p. 252). On nitro-aerial spirit see Frank 1980; Clericuzio 1994.

recently opened up by microscopes concealed yet further depths. The young Robert Boyle spent more time on anatomy, 'conversing with dead and stinking Carkases', than he would later. He thought that the hairs on a mite's leg must themselves be composed of 'unimaginably little' parts, and asked 'how much more subtle must be the animal spirits that run to and from in nerves suitable to such little legs?' ('Of Atoms' (1650), quoted by Frank 1980: 95).[10] Henry Power in 1664 likewise wrote of subtle animal spirits running to and fro in the 'prodigiously little spindle-shank'd leggs' of mites in cheese (*Experimental Philosophy*, in Vickers 1987: 92). As in debates about the preformation of embryos (Roe 1981: 45–88), inability to see or measure postulated entities could always be deflected by reference to human sensory limitation.

Without the spirits . . .

There may be a second reason for the spirits' survival beyond the Swammerdam/Steno critique. Steno's antipathy to theoretical entities and hypothesising left certain areas of physiology and neurophilosophy all but inaccessible. K.D. Keele (1967: 199) comments on Steno's rational critique of Thomas Willis' rash speculations on cerebral spirits: 'Steno was right: so right indeed that he himself made no other contribution to cerebral physiology. He abandoned the physiology of the brain as a mystery known only to God.'[11] Despite their commitment to mechanism in muscle physiology, neither Steno nor Swammerdam wanted to pursue mechanistic accounts of cognitive function: they turned, respectively, to Catholicism and to Antoinette Bourignon's charismatic religion.[12] Spirits theory had never been restricted in domain to muscle physiology, and the realms of cognition, perception, memory, emotion, and so on, remained irresistible to natural philosophers of other persuasions.

It is not quite the case that those who rejected animal spirits were thereby restricted to theorising muscular motion alone: Hartley would employ Newtonian vibrations (rather than spirits) in sophisticated accounts of memory and other cognitive functions. But animal spirits did encourage flirtation with suggestive metaphors which were unavailable to critics. This raises

10 On Boyle's uses of animal spirits see MacIntosh (1983: 332), who quotes a reference in Boyle's *Languid and Unheeded Motion* (1685), to 'minute' and 'invisible' animal spirits of which 'prying Anatomists have not been able in dissected Nerves to discern so much as the channels, through which they pass' (Boyle 1772/1968: IV: 34).

11 The point that Steno's discourse had a 'shattering effect' on European neuroscience was made by Max Neuburger: see Meyer and Hierons 1965: 147. On Willis and Steno, compare Bynum 1973: 458.

12 I do not intend here to make the psychological claim, for either of the two men, that there were direct causal connections between their attitudes to religion, to metaphysics, and to theoretical entities in physiology. But at least nothing in two outstanding recent studies rules out such connections: see Kardel 1994b on Steno, and Ruestow 1996: 105–45 on Swammerdam.

an irksomely evaluative question for the historian of neurophilosophy, which forces an attitude towards our current mind/brain sciences. Was this retreat from neurocognitive explanatory ambition a necessary theoretical purification, the abandonment of metaphorical language which could only be 'a deterrent to the development of a more scientific hypothesis of nervous action' (Brazier 1958: 203)? Or was the establishment of a more insulated and isolated neuroscientific discourse an unnecessary prudery, the cowardly refusal to countenance microstructures of cognition?

'Newtonian' physiology is a useful test case. Newton's authority buttressed scepticism about spirits by enforcing positivist caution about hypothetical entities: Mary Brazier (1958: 204) tells us that Newton, 'the greatest scientist of his time', found animal spirits theory to be 'not acceptable'. Newton's early interest in memory and imagination was coupled with doubts about the evidence for animal spirits (McGuire and Tamny 1983: 487–8; Newton to Oldenburg 1675, in Turnbull 1959: 366–70): he retreated, like Steno, from cognitive theory, and later reinterpreted animal spirits in line with his changing views on ethers (Iliffe 1995: 445–51). The views on spirits of eighteenth-century followers of Newton are hard to interpret, but it is clear that many were aware of the potential threat which uncontrolled mechanical neural processes posed to reason, and constructed their physiology to suit what Iliffe calls a 'theological politics of self' (1995: 453–8). Some rejected the 'received Opinion' about spirit's role in muscular motion, complaining that 'such a Fluid is altogether unfit for such work' and preferring vibrations, since 'Sir Isaac Newton is of [that] opinion' (Bryan Robinson, in Hoff 1936: 165): others retained nerve fluids reconstrued as non-mechanical active principles; for example, during the 1740s, Richard Mead saw melancholy as 'alterations . . . in that active liquor, by which the mind governs the body' (Jackson 1986: 123–4). Just as Newtonian cosmologists denied the need for Cartesian vortices and other hidden causes simply to cover apparent gravitational action at a distance, preferring just to describe observed phenomena (Hesse 1961/1970: chs. 6–7), so the tendency of Newtonian physiology was to deny, or at least neglect, theoretical need for hidden neural processes to fill the temporal distance between past and present which memory bridges.

The institutional and rhetorical success of Newton's disciples in many fields (Schaffer 1980: 58–71, 1990; Shapin 1980) did not extend to physiology, where the desired mix of mathematical analysis and experimental manipulation failed. Attempts to quantify by transporting physical formulae to the life and cognitive sciences had limited application: James Keill and Stephen Hales integrated experiment and number in limited domains, but Thomas Morgan's 1725 description of imagination (force) as the product of nerves (mass) and animal spirits (acceleration) was wishful (Rousseau 1969/1991: 11). Pitcairne's programme for establishing the 'Laws and Properties of the Fluids and Canals

of Human Bodies' was meant to purge physiology of the 'uncertain wandering' of multiple bodily fluids and other poetic fictions, but foundered on the difficulty of quantification, remaining 'more Cartesian than "Newtonian" (Brown 1968/1982: 192–237; Guerrini 1987). The 'Newtonianism' in Richard Mead's physiology was, likewise, 'spurious' (Coleman 1970: 328). Brown's history of the movement (1968/1982: 308–53, 1987) ends with a loss of direction and 'sudden demise of Newtonian physiology' in the 1730s.

We can, then, construct from the Newtonian case a bare hint of an answer to the puzzle of the spirits' survival. Those who remained true to the ideal of freedom from hypothesis and cared little for invisible body fluids found theorising beyond muscular motion all but impossible. Perhaps, despite the experimental and conceptual objections to animal spirits, the theory survived because of the possibilities it opened, in physiology and culture, for connecting domains that more sober approaches just could not reach. The very linguistic and conceptual confusions and conflations at which cautious critics carped were the sources of the enabling discursive power of spirits talk. Such talk permitted theorists to approach cognition without dreaming of a language purged of body, culture, and context, and immediately raised important, difficult, and resistant questions about order and chaos in self, memory, and mind.

If there is anything in this diagnosis, and animal spirits survived in part because of their rhetorical uses, it should be the case that change in the cultural image of the cognitive functions they were meant to underpin would affect their fate. Chapter 10 below suggests that the timing of the spirits' decline depended in part on increased awareness that they could not play the required extra-physiological roles. Eighteenth-century assumptions and ideals about memory and personal identity would sit less and less well with animal spirits, beating and ferreting around the brain with rare and random violence. Before returning to the ontological narrative, I attempt a final sketch of the wider cultural setting.