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Chapter 4

Human Brain and Human Mind

The *Discourse on the Anatomy of the Brain* and its philosophical reception

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1. Introduction

The study of the anatomy of the brain has always had an ambiguous relationship with philosophical discourse on mental faculties.¹ Distinguishing the subject matter of each discipline is not an easy task. The philosophical reception of Nicolas Steno's *Discourse on the anatomy of the brain* (1669) provides a good illustration of the way in which they are intertwined and puts into focus how the anatomical study of the brain can be metaphysically instrumentalized.

The *Discourse* was pronounced in Melchisédec Thévenot's Parisian salon in 1665 and published in 1669. It essentially consists in a thorough review of the contemporary state of anatomical studies of the brain. It includes a description of the most widespread errors regarding the structure of the brain, a list of reasons why such errors had so far been committed, and a brief proposal to amend the discipline. At first sight, this modest and technical text contains no philosophical claims, nor does it propound a thesis about the nature of the soul or its relationships to the brain. It does not even connect cerebral structures with

¹ I use the following abbreviations: DESCARTES: Ariew = *Philosophical Essays and Correspondence*, ed. R. Ariew, Indianapolis/Cambridge: Hackett 2000. AT = *Œuvres de Descartes*, ed. C. Adam and P. Tannery, new presentation by B. Rochot and P. Costabel, Paris: Vrin-CNRS 1964-1974. STENO: *Discours* = *Discours sur l'anatomie du cerveau*, Paris: Robert de Ninville 1669. *Epistolae* = N. Steno, *Epistolae et epistolae ad eum datae, quas cum proomio ac notis Germanice scriptis edidit*, ed. G. Scherz, Copenhagen: A. Busck 1952. Maquet = *Nicolaus Steno: Biography and Original Papers of a 17th Century Scientist*, ed. T. Kardel and P. Maquet, Berlin: Springer 2013.

animal or mental functions. Yet it received considerable and durable philosophical attention, doubtless because it includes a short refutation of the Cartesian account of brain anatomy. Hence Jean Chapelain, a Parisian scholar who adhered to Gassendi's philosophy, emphasized the polemical importance of Steno's *Discourse*:

Stensen the Dane has performed the most marvelous experiments ever in this field. He has even forced the obstinate and dogmatic Cartesians to [p. 88] admit the error of their leader with regard to the gland of the brain and its function [...], on which he based all the operations of the reasonable soul.²

This quotation is famous in the history of Cartesianism. Afterwards, it became standard to appeal to Steno's authority in order to contrast natural man with the man invented by Descartes's ingenious mind (like Leibniz did)³ or even to discredit the idea of dualistic mind-body interaction, by pointing to Descartes's somewhat fanciful brain anatomy (like Spinoza and, long after, Franz Gall did.)⁴ In short, the long story of the *Discourse*'s philosophical reception suggests that Steno, in the *Discourse*, took a more general stand against the impasses of dualism itself. And such a hypothesis appears all the more legitimate if we consider Steno's criticism of the philosophy of Descartes in later texts, notably his letter to Spinoza, *Ad novae philosophiae reformatorem* (1675):

Scrutinize, I pray, all those demonstrations of yours and bring me just one which shows how the thinking thing and the extended thing are united [...]. So the entire philosophy of Descartes, however diligently examined and reformed by you, cannot

² Thévenot to Huet, 6 April 1665, in J. Chapelain, *Lettres*, ed. T. de Laroque, Paris: Imprimerie Nationale 1883, vol. II, p. 393, note 3; trans. by G. Scherz, in *Nicolaus Steno's Lecture on the Anatomy of the Brain*, Hafniae: A. Busck 1965, p. 70.

³ Leibniz, *De la philosophie cartésienne*, 1683–1685 (?), in *Sämtliche Schriften und Briefe*, Berlin: Akademie-Verlag 1923–, series 6, band 4, p. 1486: “Mr. Steno was disabused by Cartesianism when he discovered just how much the human body truly was from Descartes's man.”

⁴ B. Spinoza, *Ethics*, V, Preface, in Spinoza, *Complete Works*, ed. M. L. Morgan, trans. S. Shirley, Indianapolis/Cambridge: Hackett 2002, p. 365. For Gall, see *Anatomie et physiologie du système nerveux en général et du cerveau en particulier*, Paris: F. Schoell 1810, p. 24 (for a critique of the idea that the soul is simple) and p. 316-317 (for the allusion to Steno's critique of Descartes's fanciful brain anatomy.)

explain to me in demonstrative form even this single phenomenon, how the impact of matter on matter is perceived by a soul united to matter.⁵

Inferring a refutation of the so-called metaphysical dualism⁶ from the rejection of Descartes's brain anatomy is, however, questionable for two reasons. [p. 89] Firstly, Steno's *Discourse* does not only refute Descartes' description of the pineal gland. It also refutes Thomas Willis's cerebral anatomy, which was philosophically closer to Gassendi, as well as the hypothesis of the "Ancients"⁷ with regard to the cerebral seats of memory, imagination and judgment—both positions that are not regarded as dualistic. Secondly, and most importantly, the approach to brain function that Steno recommends seems itself to depend on the idea of a dualism between *res extensa* and *res non extensa*.

The aim of this chapter is threefold: (1) to show that Steno's position in the *Discourse* is irreducible to the ways in which it was used both by Descartes's detractors and by his followers; (2) to clarify the link between Steno's anatomical critique of Descartes and his metaphysical position, or lack thereof; (3) to contribute to current discussions regarding "cerebral localizations," i.e. the assignment of specific mental functions/faculties to specific parts of the brain. I will proceed in three steps. First, I will present the specificity of Steno's criticism of Descartes in the medical landscape of the time, providing the necessary background for understanding its reception by late seventeenth-century philosophers. Next, I will define Steno's position as "critical experimentalism" and discuss the question of a

⁵ Steno, *Opera theologica*, ed. K. Larsen and G. Scherz, Copenhagen: A. Busck 1944, vol. I, p. 101, trans. in Spinoza, *Complete Works*, Letter 67A, p. 933 [orig. *Excute, quaeso, omnes demonstrationes tuas, et vel unam mihi afferto de modo, quo cogitans et extensum uniuntur [...] [A]deoque omnis Cartesii philosophia, ut ut quam diligentissime a te excussa et reformata, non possit mihi vel hoc unicum phaenomenon demonstrative explicare, quomodo nempe materiae in materiam impulsus ab anima materiae unita percipiatur*].

⁶ I will not discuss here the relevance of such a label which would require a study of the *Passions of the Soul* and the *Sixth Meditation*. By "dualism," I simply mean the substantial distinction between a *res extensa* and a *res cogitans*.

⁷ The hypothesis that Steno presents as being that of the "Ancient" was usually attributed to Thomas Aquinas, Duns Scot, Albert the Great, Avicenna and Averroes. It was also defended by Ambroise Paré (1509?-1590). See his *Œuvres complètes*, ed. J.-F. Malgaigne, Paris: J.-B. Baillière 1840-1841, p. 216-17, where he localizes imagination in the two first ventricles, judgment in the third ventricle and memory in the fourth ventricle. Many Ancient physicians, however, defended an alternative thesis inspired by Galen according to which there are no distinctive "seats" in the brain. In the French Renaissance, this was the case of Andre Du Laurens (1558-1609).

possible influence of Descartes on Steno's methodology. Finally, I will show how a late manuscript by Steno sheds new light on the issue of dualism in cerebral anatomy.

2. A Factual Critique of Descartes

The *Discourse on the Anatomy of the Brain* begins with a confession of ignorance: in 1665, Steno admits, anatomists ignore both the true structure of the brain and the nature of its main parts, be it the animal spirits, the white and grey substance, or the ventricles. What learned people think they know is at best uncertain. As proof, Steno very briefly invokes the anatomical "system" of the "Ancients," Willis's system and some of Descartes' hypotheses, all of which [p. 90] can be proved wrong by means of accurate anatomical demonstration.⁸ Next, Steno goes on to explain the reasons for these mistakes, which are due partly to the softness and fragility of the brain, partly to the methods of dissection, and partly to public dissections in anatomical theaters, which were mainly planned to distract. Finally, Steno indicates technical and institutional ways to improve brain anatomy, such as the invention of a circular saw or drugs softening the skull, the establishment of a new taxonomy, or the development of comparative and pathological anatomies. Thus, the critique of Descartes constitutes only a small part of the text. Steno does however refer to the "pineal gland," in which Descartes identified the seat of the common sense,⁹ as the "most famous" anatomical issue "of this century."¹⁰ Moreover, the discussion of Descartes' descriptions of the brain is more detailed and better argued than his discussions of others descriptions, being based on a series of citations. Steno carefully summarizes Descartes' main propositions regarding the pineal gland and its surrounding parts, on which Descartes had based all of his physiological explanations of mental functions such as imagination, memory, attention, will, and sensory perception. According to Steno, contrary to what Descartes claimed, the pineal gland was not

⁸ In Steno's *Discourse*, *démontrer* means roughly "to dissect and to show."

⁹ See Descartes to Mersenne, 24 December 1646, in AT III, p. 264: "[T]he [pineal gland] is the only solid part in the brain that it is unique, therefore it should be the seat of the common sense, that is to say the seat of the thought and consequently of the soul [*il n'y a que la [glande pinéale] de partie solide en tout le cerveau, qui soit unique, il faut de nécessité qu'elle soit le siège du sens commun, c'est-à-dire de la pensée, et par conséquent de l'âme.*]" See also *Passions de l'âme*, art. 32, AT XI, p. 353.

¹⁰ N. Steno, *Discours*, p. 43, trans. Maquet, p. 519 [orig. *Je vous en rapporterai ici un exemple, dans une question Anatomique, la plus fameuse de ce siècle. Ceux qui nient la continuation de la glande pinéale avec la substance du cerveau...*].

situated in the middle of the ventricles or cerebral cavities; it was not mobile; and it was not surrounded by arteries. Given its structure, the gland could not move from side to side without breaking apart; given its position, the gland could not be on the pathway of the so-called animal spirits, this neuromuscular fluid composed of the most subtle particles of the blood that were thought to be responsible for the animal sensory-motor functions.

These criticisms are decisive: it was mainly by referring to various inclinations of the gland that Descartes explained the diversity of perceptions potentially felt by the soul.¹¹ If, however, as Steno held, the gland is neither suspended [p. 91] nor mobile it cannot contribute to the transmission of sensory impressions. If the gland is not placed in the middle between the four ventricles, nor on the pathway of the animal spirits, it cannot account for voluntary movement, attention, or even memory.¹² However, no matter how disastrous they could seem to Cartesian anthropology, such psychophysical consequences were not mentioned by Steno in the *Discourse* at all. Steno simply noted that disproving the existence of arteries around the gland was “a matter of no little consequence for the system of M. Descartes, since the separation of the spirits and their movement depend on it.”¹³

Steno’s critique of Descartes was purely anatomical, descriptive, and morphological. Yet, precisely because it was rigorously factual, it was considered all the more decisive. Steno was neither the first nor the only one to criticize Descartes’ psychophysiology by means of anatomical arguments. For instance, in the third revised and augmented edition of the *Anatomia reformata*, which appeared in 1651, two years after the publication of Descartes’s *Passions of the soul*, Bartholin dedicated a long passage to discussing the pineal gland and a

¹¹ Descartes, *Passions de l’âme*, art. 34, AT XI, p. 354-355, trans. Ariew, p. 308: “Let us then conceive here that the soul has its principal seat in the little gland that exists in the middle of the brain, from which it radiates forth through all the remainder of the body through the mediation of the spirits, nerves [*etc.*]. Let us here add that the small gland that is the principal seat of the soul is so suspended between the cavities containing the spirits that it can be moved by them in as many different ways as there are sensible differences in the objects.”

¹² Regarding memory, see Descartes, *Passions de l’âme*, art. 42, AT XI, p. 363, trans. Ariew, p. 311: “Thus when the soul wishes to recollect something, this volition causes the gland, by inclining successively to different sides, to thrust the spirits toward different parts of the brain until they come across that part where the traces left there by the object we wish to recollect are found.” For the attention, see art. 43, *ibid.*: “Thus when we wish to apply our attention for some time to the consideration of one particular object, this volition holds the gland for the time being to the same side.”

¹³ Steno, *Discours*, p. 21, trans. Maquet, p. 513.

six point refutation of the Cartesian description.¹⁴ In his *Cerebri anatome* published in 1664, Thomas Willis briefly mentioned Descartes' account of the pineal gland and rejected the functions that Descartes ascribed to it.¹⁵ No other [p. 92] criticism however proved to be as influential as Steno's. There are several explanations for this:

First, a comparison with Willis's or Bartholin's arguments reveals that, contrary to what could be found elsewhere, Steno's critique of Descartes remained very faithful to the Cartesian texts and, partly for this reason, could be considered particularly harmful to Cartesian anthropology.¹⁶ According to Bartholin's criticism in the *Anatomia reformata*, the pineal gland was an ignoble gland placed on the pathway of cerebral "excrements." In addition, Bartholin argued, it was a very small, soft, and colorless part of the brain.¹⁷ These features allegedly prevented the gland from being the seat of *common sense*, understood as the part of the brain that receives and gathers sensible *species*, i. e. the images or representations

¹⁴ See T. Bartholin (ed.), *Anatomia ex Caspari Bartholini parentis Institutionibus, omniumque recentiorum & propriis observationibus tertium ad sanguinis circulationem reformata, cum iconibus novis accuratissimis*, Lugdunum Batavorum: Franciscum Hackius 1651, p. 336-337. For a more detailed account, see R. Andrault, "Introduction," in N. Sténon, *Discours sur l'anatomie du cerveau*, ed. R. Andrault, Paris: Classiques Garnier 2009, p. 7, and R. Andrault, C. Crignon, S. Buchenau, A.-L. Rey (eds.), *Médecine et philosophie de la nature humaine de l'âge classique aux Lumières. Une anthologie*, Paris: Classiques Garnier, 2014, p. 60-61. Thomas Bartholin was Steno's preceptor at the University of Copenhagen in 1656.

¹⁵ T. Willis, *Cerebri anatome, anatome: cui accessit Nervorum descriptio et usus*, London: Martyn and Allestry 1664, chap. XIV, p. 169.

¹⁶ Albeit without mentioning him by name, Louis de La Forge's *Traité de l'esprit de l'homme et de ses facultés et fonctions et de son union avec le corps suivant les principes de René Descartes* (Paris: Theodore Girard 1666) responds to Steno's objections to Descartes' localization of the pineal gland. La Forge mainly argues against the claim that Descartes' brain anatomy is impossible. Such a strategy implies casting doubt on the accurateness of Steno's public dissections and appealing to anatomical consensus, i.e. the very consensus challenged by Steno in the *Discourse*. More generally, La Forge evokes possible differences between a living and a dead brain as well as between animal and human brains in order to dismiss critique based on public dissection and experimentation. See L. de La Forge, *Treatise on the Human Mind*, ed. and trans. by D. Clarke, Dordrecht: Springer 1997, p. 152-53: "How is there room to deny that this gland belongs to the ventricles since all the anatomists agree that is originates from two ligaments of nerves from the surface of the medullar trunk [...]? [...] Thirdly to their objection that this gland cannot move, I reply that if they can convince us that all the parts of a living animal brain are as compacted as those of the head of a dead calf, their objection may be acceptable and we would possibly agree with it. But there is no reason to believe that is the case while the animal is alive [...]. There is nothing therefore to prevent our little gland from being the principal seat of the soul."

¹⁷ For a more detailed account, see R. Andrault, *La vie selon la raison. Physiologie et métaphysique chez Spinoza et Leibniz*, Paris: Honoré Champion 2014, p. 308.

of objects.¹⁸ Hence, Bartholin evaluated Descartes's brain anatomy using criteria and terms absent from Descartes's texts. He noted for example that Descartes' system was impossible because the nerves did not touch the pineal gland. But Descartes never maintained this, even though he argued that the pineal gland was on the pathway of the animal spirits. Bartholin also mentioned "sensible species" that the gland could not gather due to its small size. For this reason, Louis La Forge, in the remarks he added to [p. 93] the first French edition of Descartes' *Man* in 1664, had no difficulties in refuting Bartholin's famous criticism point by point, arguing for instance that such criticism mistook sensible species for "small pictures of tapestry depicted in the back of the eye."¹⁹ In fact, according to Descartes, what is transmitted from the perceived objects to the seat of the common sense, i. e. the pineal gland, are only the mechanical repercussions of nervous movements.²⁰ As for Willis, he used the size of the pineal gland to refute Descartes' notion that it is the seat of soul. His reasoning was the following: animals have very little imagination and memory – two mental faculties that allegedly depend on the soul. Thus, if the pineal gland were the seat of the soul as Descartes held, or even simply if the gland played an important part for these mental faculties, it should be smaller in animals. Anatomy demonstrates that this is not the case. Therefore, the pineal gland is not the seat of the soul:

Below the chambers of the Optick nerves [...] is placed the Pineal Glandula [...]; this is not only found in Man and four-footed Beasts, but Fowls and Fishes [*sic*] also are endued with the same. Wherefore, although from hence it may be concluded, that this is of necessary use; yet we can scarce believe this to be the seat of the Soul, or its chief Faculties do arise from it; because Animals, which seem to be almost quite destitute of

¹⁸ The status of those species varies. For someone like Du Laurens, they appear at first to be material since they emanate from material objects. Nonetheless, their reception through the brain and treatment by reason can make them immaterial and universal (see *Toutes les œuvres de M. A. du Laurens*, trans. Th. Gelée, Rouen: Raphael Du Petit Val 1621, p. 308-309.) Such mixing of material and immaterial components in the processes that are first physiological, then intellectual, does not appear to be problematic to him.

¹⁹ L. de la Forge, "Remarques de Louis de La Forge," in Descartes, *De l'homme*, Paris: Charles Angot 1664, p. 321.

²⁰ On this point, see M. Fichant, "La géométrisation du regard. Réflexions sur la *Dioptrique* de Descartes," in *Philosophie* 34 (1992), p. 45-69, reedition in M. Fichant, *Sciences et métaphysique dans Descartes et Leibniz*, Paris: Presses Universitaires de France 1998, p. 27-57.

Imagination, Memory, and other superior Power of the Soul, have this Glandula or Kernel large and fair enough.²¹

But one could reply to Willis that the size of the gland did not necessarily change anything about its specific psychophysical role in living individuals endowed with thinking souls. Contrary to both Bartholin and Willis, Steno proposed a rigorously factual criticism and carefully avoided over-interpreting Descartes's texts. He contented himself with quoting Descartes's *Treatise* and demonstrating how Descartes's various anatomical statements regarding the gland could be firmly contradicted by public dissection.

Next, Steno's celebrated skills as an anatomist and public dissector made his refutation of Descartes particularly convincing. According to the *Journal des sçavans* of March 1665, during his stay in Paris Steno publicly dissected bodies [p. 94] or organs every day,²² and his skills at doing so were uniformly praised by those who were lucky enough to attend the demonstrations, either at the *École de médecine* or in Thévenot's salon in Paris. The enthusiasm of the public is for instance palpable in André Graindorge's letter:

This Steno is causing a sensation. This afternoon we saw the eye of a horse. To tell you the truth, compared with him we are only apprentices. [...] He is always dissecting. He has an unbelievable patience and through practice he has gained a unique expertise.²³

As we have already seen, Chapelain made similar kinds of comments, adding that Steno "outshined all the Ancients and all the Moderns in this sort of thing [anatomy]."²⁴ Thus, through his public dissections, Steno had earned an audience and a trust that goes a long way in explaining the importance given to his lecture.

²¹ T. Willis, *Cerebri anatome*, 1664, p. 169, trans. in *Practice of Physicks*, London: printed for T. Dring, Ch. Harper and J. Leigh 1684, p. 87.

²² See *Journal des sçavans*, 23 march 1665, ed. De Houdeville, Amsterdam: Pierre Le Grand 1685, vol. II, p. 155-156.

²³ Graindorge to Huet, 9 may 1665, in L. Tolmer, *Pierre-Daniel Huet, humaniste physicien*, Bayeux: Colas 1949, p. 330, trans. in O. P. Grell, "Between Anatomy and Religion: The Conversions to Catholicism of the Two Danish Anatomists Nicolas Steno and Jacob Winsløw," in O. P. Grell and A. Cunningham (eds.), *Medicine and Religion in Enlightenment Europe*, Aldeshot: Ashgate 2007, p. 213.

²⁴ Chapelain to Huet, 6 April 1665, in Chapelain, *Lettres*, vol. II, p. 393, note 3 [orig. *Il efface tous les anciens et tous les modernes en ce genre.*"]

Finally, the nature of this audience attending the lecture at Melchisédec Thévenot's Parisian salon arguably played a role in explaining the success of the *Discourse*. Not much is known about the exact circumstances under which Steno presented his lecture, about the people who attended it,²⁵ or just how similar the text published in 1669 was to the lecture Steno really gave in 1665.²⁶ The content of the published *Discourse* and the reactions it [p. 95] prompted from the learned community do however suggest that it answered a specific request coming from natural philosophers already familiar with Descartes's philosophy who were seeking to challenge the accuracy of Cartesian science through new observations and experiments. Among the scientists who attended Steno's lecture in Thévenot's salon, or had heard of it, Christiaan Huygens and Reinier de Graaf were eager to read Steno's text as the kind of experimental refutation of Descartes's brain anatomy that until then had been lacking.²⁷ Indeed, throughout the 1660's, Descartes's anatomy had already become the matter of a public debate that went far beyond Descartes's own texts. Bartholin, for instance, did not address his criticism to Descartes himself but rather to "Cartesian followers", just like Steno did in the *Discourse*.²⁸ And Steno should be taken seriously when he stressed that his

²⁵ Between autumn 1664 and spring 1665, at least, Auzout, Petit, Huygens, Borch, Steno and Swammerdam met at Thévenot's home. Thévenot hosted Swammerdam and Steno in Paris and Issy for nearly a year. Regarding the audience at Steno's lecture and the conflicting hypotheses about whether this audience was Cartesian or anti-Cartesian, see Andrault, "Introduction," p. 17. Sophie Roux casts doubt on what she calls a "continuist genealogy, according to which an uninterrupted line connects one society to the next, and all of them to the *Académie des sciences* ("Was there a Cartesian Experimentalism in 1660s France?" in M. Dobre and T. Nyden (eds.), *Cartesian Empiricisms*, Dordrecht: Springer 2013, p. 47-88, p. 59). It is this hypothesis that commentators usually refer to when listing the members of the Thévenot circle: they assume that the members of the *Académie de Thévenot* were roughly the same as the members at the *Académie de Montmor*.

²⁶ It is not impossible that the text remained unchanged between the lecture in the spring of 1665 and the publication in 1669. See for instance Chapelain's letter to Steno, 15 March 1666, *Epistola* 20, in Steno, *Epistolae*, vol. I, p. 187: "Mr. de Graaf [...] asked me if your *On the Brain* had already been published. It ought to be done, since when you left, so little was left for it to be done [*Mr de Graaf [...] m'a fait demander si vôtre Du cerveau était publié. Cela devrait bien être fait, puisque quand vous partîtes d'ici il y avait si peu de choses encore à faire.*]"

²⁷ For de Graaf, see note 26 above. For Christiaan Huygens, see the letter from Thévenot to Huygens, 18 September 1665, in C. Huygens, *Œuvres complètes*, ed. Société hollandaise des Sciences, Den Haag: Martinus Nijhoff, 1880-1950, vol. V, p. 488. For Chapelain, see also his letter to Steno, 8 December 1665, in Steno, *Epistolae*, vol. I, p. 184.

²⁸ Bartholin's *Anatomia reformata* (1651) mentions Meyssonier, Regius and Hogelande as "*Cartesii sequaces*" (*op. cit.* p. 336). We could add to them Schuyl, Clerselier, Gutschoven and La Forge, who edited, illustrated, and wrote the commentary in Descartes's *De Homine* (Leyde 1662) and *L'Homme* (Paris 1664):.

criticism was addressed to Descartes's friends, i.e. to the physicians who mistook Descartes's "man" for natural man, rather than to Descartes himself. The latter, Steno suggested, deserved respect as a philosopher who had found a way to explain human functions with the same evidence as we explain the functions of a machine.

It is thus not surprising that, when criticizing Descartes in the preface of the fifth part of his *Ethics*, Spinoza chose to use anatomical remarks that can be found in Steno, rather than the ones from Bartholin. Thus, in this preface, in addition to a metaphysical refutation of Descartes' theory of voluntary actions, Spinoza remarks: "There is the additional fact that [Descartes'] gland is not to be found located in the middle of the brain in such a way that it can be driven about so easily and in so many ways, nor do all nerves extend as far as the cavities of the brain."²⁹ Such a statement is surprising, given Spinoza's customary prudence when speaking of empirical, and especially medical, issues. In the *Ethics*, he restricts himself to considering the human body very abstractly as a complex union of soft, fluid, and solid parts, and refrains from naming the various parts of the human body according to any anatomical taxonomy. Nevertheless, [p. 96] Spinoza's anatomical remarks attest to the fact that philosophers of the time took Descartes' anatomy seriously—seriously enough to carefully quote and refute it even when they had sufficient reasons to dismiss Descartes' union of the soul and the body on metaphysical grounds. For Spinoza, for instance, the very idea of a proportion between the power of a motion and the strength of a will is inconceivable and the notion of a causal action between the two was already "more occult than any occult quality": "And surely, since will and motion have no common standard, there cannot be any comparison between the power or strength of the mind and body, and consequently the strength of the latter cannot possibly be determined by the strength of the former."³⁰

The enthusiasm of Thévenot's circle for the *Discourse*, as well as Spinoza's keen interest in the brain dissections performed by Steno in Leiden in 1661-1662,³¹ go to show that the search for a cerebral seat of sensory-motor coordination had become a major issue for

²⁹ Spinoza, *Ethics*, V, Preface, trans. in *Complete Works*, p. 365.

³⁰ Spinoza, *Ethics*, V, Preface, trans. in *Complete Works*, p. 365.

³¹ See P. Totaro, "Ho certi amici in Ollandia: Stensen and Spinoza," in K. Ascani, H. Kermit and G. Skytte (eds.), *Niccolo Stenone (1638-1686): anatomista, geologo, vescovo*, Romae: L'Erma di Bretschneider 2002, p. 27-38, p. 32; S. Spinoza, *The Vatican Manuscript of Spinoza's Ethica*, ed. L. Spruit and P. Totaro, Leiden: Brill 2011, p. 10 and p. 68. According to Steno's denunciation of Spinoza to the Inquisition from 1677, Spinoza "paid [Steno] daily visits to see the anatomical investigations of the brain that [he] carried out on several animals in order to discover the seat where motion begins and sensation ends [*la sede del principio de moti ed il termine della sensazioni*]."

natural philosophers at the time, regardless of their metaphysical orientation. Indeed, no matter whether they thought the mind was corporeal or incorporeal, indivisible or divided into a sensitive and an intellectual part,³² causally connected to the body or only representatively related to it, they all believed that the integrity of the brain somehow determined the transmission of nervous stimulation, the execution of voluntary motions, and the capacities to remember and focus one's attention. To put it briefly, the interest in public dissections of the brain was not particularly surprising in a historical context defined by: 1) the Cartesian rejection of substantial forms and the subsequent redefinition of the attributes of mind and body;³³ 2) the recent debates about animal souls, the existence of which was denied by Descartes; 3) the major experimental advances in animal physiology, on topics such as the circulation of the blood, the lymphatic vessels, [p. 97] the role of respiration. All this brought hope that new discoveries on the role of the cerebral parts were also imminent.

In sum, Steno was highly praised as a dissector, did not partake in endless metaphysical discussions regarding the definition of the soul, took Descartes' neurophysiology seriously enough to disprove it with the same rigor as he disproved Willis's cerebral localizations, and rejected it exclusively on the basis of morphological description. For all these reasons, his *Discourse* became a key text for those who sought to refute Cartesian philosophy on its own grounds, and this goes a long way in explaining the success of Steno's *Discourse* in the long philosophical history of Cartesianism and anti-Cartesianism.

3. A Critical Experimentalism

Steno's brain anatomy is restricted to the mere description of forms, positions, colors, size, and connection of the parts of the brain. It is solely on this ground that Steno rejected the mistakes of Willis, those of Descartes, as well as the illustrations proposed by Vesalius or Sylvius.³⁴ The justification for restricting himself in this way was the following: One must

³² This was, roughly speaking, the Gassendist position: there is a material soul, which is sensitive and common to animals and human beings. Sensation, imagination, memory depends on the movements of the animal spirits, conceived as subtle fluid flowing from the brain toward the sense organs.

³³ See R. Ariew, *Descartes and the First Cartesians*, Oxford: Oxford University Press 2014. Ariew points out that, regardless of the diversity of doctrines put forward by the so-called "Cartesians," they all shared one common point, namely rejecting of the scholastic substantial forms.

³⁴ Franciscus Sylvius (1614-1672) was Steno's teacher in Leiden. Steno also mentions in this context Casparus Bauhinus (1560-1624) and Constantius Varolius (1543-1575) (see Steno, *Discours*, p. 26).

base hypotheses about functions only on anatomical propositions that are obvious and certain. An anatomical proposition can only be regarded as certain if several spectators and other dissectors confirm it on several occasions while adopting different ways of dissecting. As Steno stressed, it is not enough to be convinced oneself but “the evidence of the demonstration must force others to agree.”³⁵ The role of the spectators was crucial: by paying attention to every gesture of the anatomist, they were able to confirm, for instance, that some cerebral parts were really contiguous to others and that the anatomist did not modify the shape of these parts, and so on. The way of dissecting was also decisive: [p. 98] changing the approach was the only way to ensure that the dissection itself did not modify the shape and disposition of the cerebral parts. As a result, anatomical knowledge became contingent upon varied and reiterated verification by ocular witnesses. This explains why Steno deemed that most previous assertions about the brain and its main parts were dubious. As he writes in the famous last paragraph of the *Discourse*:

What we have seen so far, Gentlemen, on the insufficiency of the systems of the brain, on the shortcomings of the method which has been followed to dissect and to know it, on the infinity of researches which should be undertaken on men and on animals and this in the different states in which they should be examined, on how little light we find in the writings of our predecessors and on all the attention necessary when working on such delicate pieces, must undeceive those who keep what they find in the books of the Ancients. We shall always remain in a miserable ignorance if we content ourselves with the little light they left us and if the men most prone to make these researches do not join their works, their industry and their studies to arrive at some knowledge of the truth which must be the main goal of those who reason on the subject and who honestly study.³⁶

It was in the name of such a requirement of experimental certainty that Steno rejected both the Ancients’ and Willis’s cerebral localizations. In both cases, simply pointing to the lack of a

³⁵ Steno, *Discours*, p. 40, trans. Maquet, p. 518 [orig. *Ce n’est pas même assez de s’en pouvoir éclaircir soi-même, il faut que la démonstration oblige tous les autres à en demeurer d’accord*). See also *Discours*, p. 46, trans. Maquet, p. 520: “It is not enough to pay exact attention at every moment, the manners of dissecting must also be changed; being as they are as many evidences of the truth of your operation. They can equally satisfy yourself and convince others.”

³⁶ Steno, *Discours*, p. 56-57, trans. Maquet, p. 522-23.

“convincing” element, i.e. of direct observations testifying their descriptions, is tantamount to a strict refutation. The “Ancients,” according to Steno, “took the anterior ventricles for the seat of common sense and destined the posterior ones to memory so that judgment, as they say, being accommodated in that of the middle can easily make its reflections on the ideas which come from one and the other ventricle.”³⁷ But in “all that which has been asserted hitherto to establish this opinion, there is nothing convincing.”³⁸ Even worse, the third ventricle that they based their opinion on did not exist in the way they described it. According to Steno’s summary, Willis had put “common sense in the *corpus striatum* or striated body, imagination in the *corpus callosum* and memory in the cortex or in the greyish substance which envelops the white one.”³⁹ In fact, Willis’s system is a bit more complex and, so [p. 99] to speak, dynamic.⁴⁰ But this matters little here.⁴¹ What does matter is the way in which Steno dismisses these hypotheses:

How can [Willis] be so assured to make us believe that these three operations occur in the three bodies which he destines to them? Who can tell us whether the nervous fibres start in the *corpus striatum* or whether they rather pass through the *corpus callosum* up to the *cortex* or to the greyish substance? Assuredly, the *corpus callosum* is so unknown to us that as long as one has some mind, one can say anything about it.⁴²

According to this statement, the lack of certainty fully justifies dismissing any assumption. Willis was explicit about the fact that anatomy itself did not allow him to say anything about the *corpora striata*. Like Descartes, his conjectural reasoning was based on technical

³⁷ For such a system, see Ambroise Paré, quoted in note ### above.

³⁸ Steno, *Discours*, p. 11, trans. Maquet, p. 510.

³⁹ *Ibid.*

⁴⁰ Put briefly, for Willis, the flow of the animal spirits or “sensory impressions” from the center (the striated body of the white substance) toward the periphery (the cortex) accounted for the imagination, while the flow from the periphery back to the center accounting for memory (images were conserved in the folds of the cortex.) As for the common sense, it was the cerebral location prolonging the spinal cord where the sensory impressions flowing in the nerves coming from the various sense organs gathered together, determining the sensory perception or internal sense (see Willis, *Cerebri anatome*, chap. XI, p. 72.)

⁴¹ Malebranche gives the same account of Willis’s position. See *The Search after Truth*, ed. and trans. T. M. Lennon and P. J. Olscamp, Cambridge: Cambridge University Press 1997, Book II, chap. I, § 2, p. 89.

⁴² Steno, *Discours*, p. 11, trans. Maquet, p. 511 [orig. *Quelle assurance peut-il donc avoir pour nous faire croire que ces trois opérations se font dans les trois corps qu’il leur destine?*]

analogies with the way that machines worked. But that did not mean that his claims on the subject were completely devoid of experimental support:

As to the offices and uses of the streaked bodies [*corpora striata*], though we can discern nothing with our eyes, or handle without our hands, of these things that are done within the secret conclave or closet of the brain; yet, by the effects, and by comparing rationally the Faculties, and Acts, with the Workmanship of the Machine, we may at least conjecture, what sort of works of the animal function, are performed in these or those, or within some other parts of the head; especially because it plainly appears, that the offices of the interior motions, and senses, as well as the exterior, [p. 100] are performed with the help of the animal spirits, ordained within certain and distinct paths, or as it were small little pipes.⁴³

Steno, however, refused any conjecture that could not be ascertained by witnesses, or that was not observable either directly (through anatomical demonstration) or indirectly (through compared vivisections and complex experimental procedures.)⁴⁴ This also applied to the question of animal spirits, on the nature of which there was no certainty. As for the functional hypotheses on the use of the anatomical parts revealed by dissection, they were accepted as falsifiable premises that one should endeavor to convincingly refute, as we can see in Steno's *Myology*.⁴⁵ In this way, irrefutable assertions are established negatively through criticizing uncertain assertions that were refutable through observation and experiment. As the *Discourse* puts it, "to pursue in all dissections a convincing certitude is difficult," but not completely impossible.⁴⁶ One may call this most striking and original feature of Steno's methodology

⁴³ T. Willis, *De anima brutorum* [1672], cap. IV, in *Opera omnia*, Lugdunum: Huguetan 1681, vol. II, p. 36, trans. S. Pordage, in *Two Discourses concerning the Soul of Brutes, which is that of the Vital and Sensitive of Man*, London: printed for Th. Dring, Ch. Harper, and J. Leigh 1683, p. 27.

⁴⁴ Cf. Swammerdam and Steno's experiments, showing that muscular contractions do not imply an increase of the volume of the muscles. See T. Kardel, *Steno on muscles. Introduction, Texts, Translation*, Philadelphia: The American Philosophical Society 1994, p. 16).

⁴⁵ N. Steno, *Elementorum Myologiae Specimen seu Musculi descriptio*, Florentiae: ex Typographia sub signo Stellae 1667, p. 30. See T. Kardel, *Steno on muscles*. p. 86, for the comparison with Popper; and, specifically about this point, see R. Andrault, "Mathématiser l'anatomie: la myologie de Stensen," *Early Science and Medicine* 15:4-5 (2010), p. 505-36, p. 526.

⁴⁶ Steno, *Discours*, p. 41, trans. Maquet, p. 518 [orig. *il est absolument nécessaire, comme je l'ai déjà dit, de chercher dans les dissections une certitude convaincante. J'avoue bien que cela est difficile; mais je connais*

“critical experimentalism.” The careful refutation of the main contemporary hypotheses about brain areas and mental functions is neither counterbalanced with hypotheses about the true organization of the brain, nor combined with psychological or metaphysical assertions about the soul or sensory-motor functions. Indeed, the *Discourse* carefully avoided all considerations not based on firsthand practice and experiment.

Steno used this critical experimentalism to reject Descartes’ brain anatomy, and yet it seems partly justified by Cartesian arguments. Firstly, the requirement of clarity and evidence that guides Steno’s refutation brings to mind Descartes’ method. In the *Discourse*, the “laws of philosophy” are depicted as what “teach us to search the truth while questioning our certitude and not to be content before having been confirmed by the evidence of [p. 101] the demonstration.”⁴⁷ In a letter about his conversion published in 1680, Steno used Descartes’ skeptical doubt against what he saw as Descartes’s dogmatism.⁴⁸ A second feature of Steno’s approach that appears to be inspired by Descartes concerns the machine analogy, to which he appealed no less than three times in the *Discourse* when explaining both his severity of judgment with regard to some of the most famous anatomists and his own silence regarding the functioning of the brain: “I did not say anything so far of the functions of the parts nor of the actions called animal because it is impossible to explain the movements occurring through a machine if the artifice of its parts is not known.”⁴⁹ He went on to state that “it remains to do what we would do for any other machine; I mean to dismantle it piece by piece and to consider what these can do separately and together.”⁵⁰ The machine analogy illustrates the importance of anatomical analysis: the description of parts is a necessary condition for understanding the functioning of the whole.

Steno’s *Discourse* represented an even more powerful tool for Descartes’s detractors, as its strict experimentalism and factual refutations were justified by arguments that seemed to be borrowed from Descartes’s philosophy. It is beyond doubt that Steno knew Descartes’ natural philosophy and epistemology very well. At the very least, he embraced the requirement of clarity and distinctness as the feature of knowledge that renders doubt

aussi que [cela] n’est pas tout à fait impossible.]

⁴⁷ Steno, *Discours*, p. 50, trans. Maquet, p. 520.

⁴⁸ See N. Steno, *Defensio et plenior elucidatio epistolae de propria conversione*, in *Opera theologica, cum prooemiis ac notis Germanice scriptis ediderunt*, ed. K. Larsen and G. Scherz, Hafniae: Arnold Busck, vol. I, p. 388.

⁴⁹ Steno, *Discours*, p. 53, trans. Maquet, p. 521.

⁵⁰ Steno, *Discours*, p. 33, trans. Maquet, p. 516.

impossible. And in 1659, Steno alluded to the necessity of testing a hypothesis regarding the role of the lungs by investigating “more carefully and systematically according to Descartes’ method.”⁵¹ One can be inspired by some methodological principles of Descartes while deploring the dogmatic understanding of Descartes’s writings by his more sectarian followers. This, apparently, was the case with Steno.

One cannot, however, reduce Steno’s critical experimentalism to Cartesian natural philosophy. First, the machine analogy was never specific to Cartesian physiology,⁵² and Descartes’s various readers used this analogy to support antithetical claims about the importance or usefulness of anatomy.⁵³ [p. 102] Moreover, Steno’s strict experimentalism faithfully reflects the way in which the *Académie Thévenot* distinguished itself from other Parisian scientific circles. According to the historians Harcourt Brown and Trevor Mc Cloughlin, this *Académie* was also known as the *Compagnie des sciences et des arts* and its program was detailed in the *Ebauche du project de ce que doit faire la Compagnie à l’avenir*.⁵⁴ The aim of this learned society was to perform as many experiments and to discover as many novelties as possible, for the use of mankind. More specifically, the aim was to strive to find out “the building and movements of the human body by the means of chemistry, anatomy and medicine, so as to preserve and restore the health that is the most precious thing in life.”⁵⁵ In order to do so, it was important “to disabuse the World of all

⁵¹ N. Steno, *Chaos-manuscript, Copenhagen, 1659, complete edition*, ed. and trans. A. Ziggelaar, Copenhagen: Munksgaard 1997, col. 37, p. 123.

⁵² See the comparison with the clock in M. A. Severino, *Zootomia democritaea*, Noribergae: Lietris Endterianis 1645, chap. I, p. 38, p. 43.

⁵³ La Forge used this analogy to defend the relevance of Cartesian hypotheses about hidden components of the human body and to illustrate the limits of anatomy (see Andrault, “Introduction,” p. 69).

⁵⁴ See H. Brown, *Scientific Organization in Seventeenth-Century France (1620-1680)*, Baltimore: William & Wilkins Cie 1934, and T. Mc Cloughlin, “Sur les rapports entre la Compagnie de Thévenot et l’Académie royale des Sciences,” in *Revue d’histoire des sciences* 28:3 (1975), p. 235, note 2. See also J. Schiller and J. Théodorides, “Sténon et les milieux scientifiques parisiens,” in G. Scherz (ed.), *Steno and Brain Research in the Seventeenth Century*, Oxford: Pergamon Press 1968, p. 162. On this, see also Roux, “Was there a Cartesian Empiricism in 1660s France?,” p. 69. For the note, see Huygens, *Œuvres*, vol. IV, p. 325-26.

⁵⁵ Huygens, *Oeuvres*, vol. IV, p. 325 [orig. *Le dessein de la Compagnie est de trauailler à la perfection des Sciences et des Arts, et de rechercher generalement tout ce qui peut apporter de l’utilité ou de la commodité au Genre humain et particulieremt a la france. Pour paruenir à ce dessein l’on trauaillera a faire des experiences et à decourir les plus de nouveautez que l’on pourra tant dans le Ciel que sur la Terre par les obseruations Astronomiques et Geographiques avec les grandes Lunettes, les microscopes, et tous les autres jnstruments necessaires. On trauaillera a apprendre plus particulierement la construction et les mouuemens du Corps*

vulgar errors that have been for so long accepted as true for lack of experiments required to discover their falseness.”⁵⁶ According to this experimental project, it was essential to leave aside religious or metaphysical topics—and if those topics were to be mentioned, it could only be incidentally, to the extent that they are related to physical matters.⁵⁷ Sophie Roux speaks of the “radical experimentalism” of this *Compagnie*, *i.e.* “the doctrine according to which the true work of those [p. 103] who study things of nature is nearly exclusively to carry out experiments in a socially closed space.”⁵⁸ Although the *Compagnie* was partly inspired by the *Royal Society* and intended to inter dialogue with it. Huygens’ program, however, shows that experimentalism was not exclusively promoted and embodied by English natural philosophers.

One may wonder where this radical experimentalism comes from. It can partly be linked to Francis Bacon whom both Thévenot and Steno read.⁵⁹ It is also possible that Thévenot’s *Compagnie* was partly guided by Descartes’s method, in particular the sixth part of the *Discourse on method*. Eventually, however, the members of the *Compagnie* strongly opposed what they saw as groundless speculation and dogmatism among the Cartesian *sectateurs*.⁶⁰ One should not overestimate the influence of figures such as Descartes and Bacon. Many natural philosophers of the time read Descartes and Bacon, but they understood and used them in different ways. Moreover, particularly in relation to Steno, one should not underestimate the theoretical effects of anatomical dissection and medical practice.⁶¹ During his student years in Amsterdam and Leiden, Steno performed many dissections in order to “demonstrate,” or bring to light, new anatomical parts and ducts, and to verify alleged discoveries claimed by colleagues. In 1661, in order to test explanations provided by Ludovic

humain par le moyen de la chymie, de l'Anatomie, et de la Medicine pour pouuoir conseruer ou restablir la santé qui est la chose la plus pretieuse de la vie.]

⁵⁶ *Ibid.* p. 326 [orig. *Enfin on s'estudiera à detromper le Monde de toutes les Erreurs Vulgaires qui passent depuis si long temps pour des veritez, faute d'auoir fait une fois les experiences necessaires pour en decouuir la fausseté.*]

⁵⁷ *Ibid.* p. 328 [*On ne parlera jamais dans les Assemblées des misteres de la Religion ny des affaires de l'Estat: Et si l'on parle quelque fois de Metaphisique, de Morale, d'Histoire ou de Grammaire etc. Ce ne sera qu'en passant, et autant que cela aura du rapport à la Physique, ou au commerce des hommes.*]

⁵⁸ Roux, “Was there a Cartesian Experimentalism in 1660s France?,” p. 65.

⁵⁹ For Steno, who read at least part of *De augmentis et dignitate scientiae*, see Steno, *Chaos-Manuscript*, col. 24, p. 81. For Thévenot, see Roux, “Was there a Cartesian Experimentalism in 1660s France?” p. 71, note 92.

⁶⁰ For Thévenot, see *ibid.*, p. 77. For Steno, see note ### above.

⁶¹ I thank Eric Jorink for having pointed this out to me.

Bils regarding the movement of the chyle, he several times repeated the same experiments on live dogs in Amsterdam, “since it is not enough to have tried once to conclude something reliable.”⁶² At the time, in anatomy, there was nothing unusual about proving a point or dismissing an opposing hypothesis publicly. Steno, however, went one step further, when he began to cast doubt on the methods of brain dissection taught by his own teachers.⁶³ It is not unreasonable to claim that Steno’s practice as an anatomist contributed to the critical experimentalism in terms of which he also understood Descartes’ method and Descartes’ requirement for “demonstration.”

In any case, this critical experimentalism is of no little consequence when it comes to the search for the cerebral seats of mental faculties, be it conscious [p. 104] perception, imagination, or memory. Indeed, his refutations of the various “systems” of the Ancients, Willis, and Descartes, are all based on two kinds of arguments. First, Steno argued, they appeal to anatomical descriptions that can be proven wrong in public dissection. Second, they provided “no certainty,” but were unreliable, gratuitous, and grounded on assertions that were not verifiable by colleagues. Under such conditions, one may wonder whether Steno’s critical experimentalism did not entirely proscribe what has been called cerebral localization, or the attempt to assign corresponding brain parts to mental functions such as memory and perception. Mental functions are by definition not directly observable by a third-party. How can one then verify by means of pure observation assertions about the cerebral seat of this or that mental faculty, especially at a time when a neurosurgeon could not perform an “awake craniotomy” on a conscious patient in order to map cortical functions?

4. An Experimental Dualism?

Steno’s strict experimentalism and strict definition of what is collegially demonstrable and what is not, suggests a strong epistemological separation, not to say dualism, between third-person bodily phenomena and first-person psychological functions.

Surely, mental operations somehow condition animal or human “actions,” as Steno called them, *i.e.* sensory-motor functions, which themselves are observable. Specifically, nervous endings in the brain may shed light on the specific locations where impulses come from or where sensory impressions end. In the *Discourse*, Steno himself said that a good way

⁶² Steno to Bartholin, 12 September 1661, in *Epistolae*, vol. I, p. 142, trans. in Maquet, p. 392.

⁶³ See Steno, *Discours*, p. 7, trans. Maquet, p. 509-510.

of clarifying brain functions would be to follow nervous terminations in the white substance. But he immediately added that the softness and fragility of the brain may prevent a thoroughgoing examination. Compared anatomy⁶⁴ and vivisection may also shed new light on the location “where motion begins and sensation ends,” to quote Steno’s terminology in his letter to the Inquisition.⁶⁵ [p. 105] According to Bartholin, the experiments conducted by Steno on fish had prompted him to localize the principle of “animal actions” in the spinal cord rather than in the brain.⁶⁶ But regardless of the experiments, two operations involved in Descartes’s cerebral localizations were proscribed by Steno’s critical experimentalism: first, to search for a principal seat of the soul or, in Descartes’ words, for a part to which the soul was more particularly united,⁶⁷ and, second, to correlate various psychophysical functions (attention, memory, imagination, will) to various kinds of cerebral movements. This last approach requires, first, that one proceeds to a “phenomenological decomposition”⁶⁸ of the mind, or that we distinguish several kinds of mental operations on the basis of the consciousness we have of them. Next, it requires that we conceive of unobserved cerebral properties or hidden movements through which mental operations can be performed. Consider for instance how, in Descartes, the inclination of the pineal gland accounts for attentiveness, or how the small filaments of the medullar part of the brain are modified by the reiterated passage of the animal spirits, retaining in their folds the recollection of things.⁶⁹ At the very least, such explanations require that one appeals to analogy and introspection.

⁶⁴ See Steno, *Discours*, p. 56-57, trans. Maquet, p. 522: “The brain is different in different species of animals. This is another reason to examine them all. The brain of birds and fishes is very different from that of man and, in animals with a brain the closest to ours, I never saw one in which I did not find some very obvious difference. Such a difference, whatever it may be, always throws some light on the researches and may teach us that which is absolutely necessary.”

⁶⁵ Spinoza, *The Vatican Manuscript*, p. 10.

⁶⁶ See T. Bartholin, *Anatome ex omnium veterum Recentiorumque Observationibus Inprimis Institutionibus b.m. parentis caspari Bartholini ad Circulationem harvejenam et vasa lymphatica quartum renovata*, Leyde: ex Officina Hackiana 1673, book III, p. 477.

⁶⁷ See Descartes, *Passions de l’âme*, AT XI, p. 351.

⁶⁸ See W. Bechtel, “Decomposing the Mind-Brain: a Long-Term Pursuit,” in *Brain and Mind*, 2002 (3), p. 229-42, and esp. 231: “[The] attempt of faculty psychology to differentiate different faculties of mind is an exercise in phenomenal decomposition.” See also p. 230 regarding to objection put forward by by Uttal according to which “many mental entities turn out on close inspection to be hypothetical constructs whose reality is impossible to validate because of the intrinsic inaccessibility of mental processes.”

⁶⁹ *L’Homme*, AT XI, p. 179.

Steno's demanding conception of anatomy precisely prevents any localization of mental operations but also proscribes establishing connections between anatomical descriptions of cerebral parts and unobservable operations. Critical experimentalism excludes from the study of bodies any property of matter that is not fully actualized in an observable quality or a local movement. Such a restriction could appear to rely on an identification of the body with mere extension (*res extensa*), but this is not necessarily the case. Steno's demanding conception of anatomical science does however imply a mechanistic conception of matter and a strong separation between what pertains to the experimental science of bodies and what belongs to introspection and conscious first-person experience. Hence, the epistemology underlying Steno's critique [p. 106] of the Cartesian conception of the pineal gland bars him from proposing any psychophysical hypotheses about the specific cerebral conditions pertaining to different mental faculties.

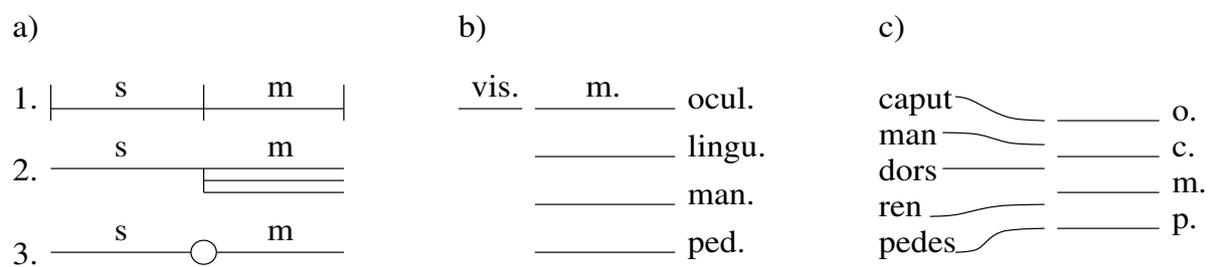
A manuscript written, it seems, nearly twenty years after the *Discourse* confirms that the absence of cerebral localization in Steno, itself stemming from the strict definition of the object of anatomy, is itself related to a strict dichotomy between *res extensa* and *res non-extensa*. The manuscript in question was found in Florence among some theological papers. It was written in Hamburg, probably in 1684.⁷⁰ It should be interpreted with caution: it contains *lacunae* and mixes physiological with normative remarks. For instance, in the middle of the text, Steno suddenly wrote, somewhat out of context, that in Spinoza there is only the study of truth and not of virtue. The aim of the paper was, it seems, to prove the existence of a non-extended intermediary between sensory and motor nerves. What matters to us is the point of departure of the demonstration which mirrors the methodological requirements set forth in the *Discourse on the Anatomy of the Brain*. Steno begins by providing physiological data restricted to third-person observations and experiments, including the distinction between, on the one hand, sensory nervous filaments through which sensations are, partly at least, communicated to what Steno calls the inside (*introrsum*), *i.e.* the white substance and the medullary substance of the brain, and, on the other hand, motor nervous filaments that

⁷⁰ I follow Scherz, the editor of the manuscript (see *Epistolae*, vol. II, p. 949). The manuscript can be found in the *Biblioteca Nazionale Centrale di Firenze*, Gal. 291, fol. 183. An English translation from the Latin by E. Collins and P. Maquet can be found in T., *Steno. Life. Science. Philosophy*, Copenhagen: Danish National Library of Science and Medicine 1994, p. 147-151.

communicate movement to the muscles from the inside. All these filaments extend from the peripheral organs or “extremities” toward the spinal cord and the brain.⁷¹

Thus, Steno does not begin by providing psychological distinctions between faculties, which he could then go on to relate to the different areas of the brain. He takes his point of departure in observable *stimuli*, emitted and received, [107] by the human body. The core of the demonstration is the following. We know that similar sensory impulses from the outside do not necessarily determine the motor-nerves from the inside in the same way. Various sensory impulses can lead to the same motor response and, conversely, a single sensory impulse may prompt various motor responses. How to account for the fact that the two kinds of nervous filaments are physically connected in such variable and complex ways? It is not possible to imagine a one-to-one connection between them, for instance, nor can some intermediary fluid explain multiple motor responses to a single sensory impulse.

Steno gives as an example the transmission of a single musical note depicted on paper through the ocular nerves. This signal can then trigger various responses, “through the nerves to the tongue, whenever it can sing an octave above or below, through the nerves to the individual fingers with which it can strike the same note [at every] octave, and also to the feet.”⁷² Steno provides the following diagrams, without however commenting upon them:



⁷¹ See Steno, *Epistolae*, vol. II, p. 949, trans. in Kardel, *Steno*, p. 147-148 [orig. *Certum est motus et sensus peragi in animalibus ex parte per filamenta nervorum, quorum alia extremitas introrsum continuatur versus substantiam albam cerebri et medullae spinalis, altera extrorsum fertur ad varias partes. Certum est filamentum nervorum, per quae sensibilibus objectorum impulsus introrsum communicator, alia esse a filamentis, per quae determinationes motuum ab intra musculis communicantur. [...] Certum ad eosdem impulsus ab extra fieri diversissimas mutationes determinationum ab intra. Certum est ad diversos impulsus ab extra saepius fieri easdem determinationes ab intra.*] In this context, “determinationes” probably means the directions (or changes of direction) of a motion.

⁷² *Epistolae*, vol. II, p. 950, trans. in Kardel, p. 148-149 (modified) [orig. *Eadem nota musica per nervos oculorum communicando fili impulsus introrsum infinitas determinationum ab intra mutations producit, per nervos ad linguam, quoties supra vel infra octavam ejus potest intonare, per nervos ad singulos digitos, quibus eandem per singulas octavas percutare potest, item et versus pedes.*]

From Nicolai Stenonis, *Epistolae et epistolae ad eum datae*, ed. Gustav Scherz, Hafniae: A. Busck, 1952, t. II, addiment. 24, p. 950.

Diagram a) shows that if the intermediary between sensory nerve (*s*) and motor nerve (*m*) were solid or fluid, then a single sensory impulse would be always followed by the same motor response or same set of motor responses. Diagram b) shows that the sight (*vis.*) of a same musical note may trigger various motor responses: various motions (*m*) of the eyes (*oculorum*), of the tongue (*linguae*), of the hands (*manuum*) or of the feet (*pedum*). Conversely, diagram c) shows how various sensory impulses can trigger the same set of motor responses: wherever someone is burned, be it on the head (*caput*), hand (*man.*), back (*dors*), waist (? – ‘*ren*’), or feet (*pedes*), it will trigger the same kind of motor response: the eye muscle will move (*o.*), the vocal chords will produce [p. 108] a yell of pain (*c.* for ‘*clamor*’), and the hands (*m.*) will move to remove the pain, or the feet (*p.*) will run away.

Stenon finally arrives at the following conclusion:

This intermediary of mine, between senses and nerves of movement, perceiving and [determining] movement, cannot be [extended], otherwise each nerve would have its own corresponding point and an impulse of the same nerves would always result in the motion of the same corresponding muscle [...].⁷³

Steno’s reasoning rests on the restriction of material properties to extension and, as a consequence of this, on the restriction of bodily modifications to the visible effects of local impulses.

It is a striking fact that Steno limits himself to third-person data and that, from those, he infers the existence of something that is precisely not physical but goes beyond the experimental query. According to Steno’s critical experimentalism, such a non-extended thing cannot be associated with a specific seat in the brain. When we summarize these various elements, they add up to the following, somewhat paradoxical situation: 1) Steno’s anatomy,

⁷³ See Steno, *Epistolae*, vol. II, p. 950, trans. in Kardel, Steno, p. 149 (modified) [orig. *Illud mei medium inter sensus et nervos motus, percipiens et determinans motus, non potest esse extensum, alias singuli nervi haberent suum sibi respiciens punctum et semper ad eorundem nervorum impulsus sequeretur idem respondentis musculi motus...*]

which rejects Descartes' conception of the human body, leads to epistemological dualism; 2) this dualism was at least once, namely in the manuscript of Hamburg, stated in Descartes' terminology, where Steno assimilates matter and extension; 3) this assimilation leads Steno to affirm that some immaterial and perceiving thing must account for the connection between sensations and motions in human body; 4) but this assimilation also implies rejecting all anatomical localization of the seat of the soul or of the various mental faculties.

By restricting his intentions to what he deems "demonstrable," Steno proposes a strictly behaviorist approach to the cerebral links between sensations and movements, contrary to all his contemporaries who rather sought to correlate their cerebral physiology with a division into mental faculties partly based on introspection. The demonstration of a non-extended intermediary between sensory and motor nerve endings cannot, in Steno, be combined with the anatomical localization of such an intermediary somewhere in the brain. [p. 109] For not only is this intermediary in itself and by definition non localizable, but Steno's experimentalism moreover prohibits any possible specification of a zone or part of the brain to which this intermediary would be particularly attached.

In turn, the impossibility of situating the seat of the mind, or the seats of mental faculties, in any specific part or parts of the brain is derived from the idea of a strict dualism between, on the one hand, *extended* observable fluids and solids endowed with local movement and modified through mechanical impulse and, on the other hand, a *non-extended* "I" who perceives and gathers sensory impulses and then selects and determines motor impulses.

4. Conclusion

We have identified in Steno a "critical experimentalism," which requires restricting experimental enquiry to the sensible properties of fluids and solids moved by local impulse, adopting an analytical approach to complex *explananda*, and submitting procedures and results to collegial verification. Such experimentalism involves a strict distinction between observable extended bodies and non-extended things lying beyond the limits of science. This dualism, implied in Steno's use of the Cartesian notion of extension in 1684, also entailed proscribing premature cartographies of the brain's cognitive functions of the kind found in the systems of the Ancients, in Willis, or in Descartes himself. Thus, Steno's anatomy brought him to embrace a dualism that clashed with the Cartesian anthropology. This dualism highlights the difficulties in combining an experimental approach to the science of living

bodies, conceived on the model of mechanics, with an explanation of the mind's functions in terms of a cartography of the brain. How to make the mind a legitimate object of an experimental science of the human body? How to connect a neuro-anatomy and physiology of sensori-motor functions with the elucidation of mental operations strongly related to those sensori-motor functions?

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