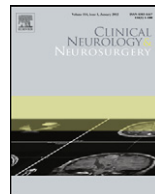




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# Beyond the pineal gland assumption: A neuroanatomical appraisal of dualism in Descartes' philosophy

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### ABSTRACT

**Objective:** The problem of the substantial union of the soul and the body and therefore the mechanisms of interaction between them represents the core of the Cartesian dualistic philosophy. This philosophy is based upon a neuroanatomical obvious misconception, consisting mainly on a wrong intraventricular position of the pineal gland and its capacity of movement to act as a valve regulating the flow of animal spirits. Should we consider the Cartesian neurophysiology as a purely anatomical descriptive work and therefore totally incorrect, or rather as a theoretical conception supporting his dualistic philosophy?

**Method:** From the various pre-Cartesian theories on the pineal organ, we try to explain how Descartes used his original conception of neuroanatomy to serve his dualistic philosophy. Moreover, we present an appraisal of the Cartesian neuroanatomical corpus from an anatomical but also metaphysical and theological perspectives.

**Results:** A new interpretation of Descartes' writings and an analysis of the secondary related literature shed the light on the voluntary anatomical approximations aiming to build an ad hoc neurophysiology that allows Descartes' soul–body theory.

**Conclusion:** By its central position within the brain mass and its particular shape, the pineal gland raised diverse metaphysical theories regarding its function, but the most original theory remains certainly its role as the seat of soul in René Descartes' philosophy and more precisely the organ where soul and body interact. The author emphasizes on the critics raised by Descartes' theories on the soul–body interaction through the role of the pineal gland.

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"We see clearly that it is just this problem before which philosophers have taken refuge in the fortress of immanence. . . Even if one of the most prominent representatives of the view [Ernst Mach (1838–1916)] had not explicitly stated this to be the case, we could readily see that all forms of the immanence idea arise from a desire to escape the psychophysical problem."

Moritz Schlick (1882–1936), *General theory of knowledge (Allgemeine Erkenntnislehre)*, Translated by Albert E. Blumberg. Springer-Verlag. 1974. p.199–200

### 1. Introduction

Until the end of the 16th century, the definition of the soul (*psukhè* or *anima*) used in occidental Europe was the one enounced

by Aristotle [1]. He defined the soul as the first actuality of a natural body that is potentially alive. It therefore represents a veritable principle of life authorizing the fulfillments of the body's potential. According to Aristotle's conception, the soul is not conceivable without the body and it is essential to the proper core activities of all living beings: vegetative (reproduction, nutrition and growth), motor and sensitive, and rationale functions.

During the 17th century and particularly under the impulse of René Descartes (1596–1650), the interactions between the soul and the body arouse several debates. With his Platonic and anti-Aristotelian posture considering the soul as an immaterial thought without any connection with life, Descartes distinguishes the corporeal substance (*Res extensa*), incapable of thought and subject to the laws of nature, and the mental substance (*Res cogitans*) totally immaterial and unsolvable by physics or mathematics. Using this dichotomy, Descartes raises the issue of the soul–body interaction. He hypothesizes that the pineal organ is the seat where the soul and the body interact. His theory mainly relies on the fact that the pineal gland is the unique organ of the brain that is not double and that has a central position within the brain:

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URL: <http://www.wix.com/berhoumamoncef/home>.

My view is that this gland is the principal seat of soul, and the place in which all our thoughts are formed. The reason I believe this is that I cannot find any part of the brain, except this, which is not double. Since we see only one thing with two eyes, and hear only one voice with two ears, and in short never have more than one thought at a time, it must be necessarily be the case that the impressions which enter by the two eyes or by the two ears, and so on, unite with each other in some part of the body before being considered by the soul. Now it is impossible to find any such place in the whole head except this gland; moreover it is situated in the more suitable possible place for this purpose, in the middle of all the concavities; and it is supported and surrounded by the little branches of the carotid arteries which bring the spirits into the brain.

Letter to Meyssonier, 29 January 1640 – page 143, vol. 3 [2]

In a preliminary reading of Descartes' *De Homine* [3], we can be surprised facing the obvious neuroanatomical errors and approximations in the book's illustrations at a moment when Andreas Vesalius [4] (1514–1564) and Caspar Bauhin [5] (1560–1624) academic anatomical works were already diffused in occidental Europe. However in order to avoid any basic purely anatomical critics of Descartes' theory on the pineal gland, it is paramount to replace his neuroanatomical conception into his dogmatic and rationalist methodological context. We recall that the Cartesian method implies that the reason is considered as the unique and decisive source of knowledge, and therefore pretends to the truth only by its a priori principle.

The aim of this work is to expose in a first part the ancient pre-Cartesian assumptions on the pineal gland before describing the neuroanatomical and neurophysiological basis of the Cartesian dualism. The last section emphasizes on the reactions to Descartes' theory on the substantial union of the soul and the body, both through anatomical, metaphysical and theological perspectives.

## 2. The pineal organ before Descartes

Numerous publications have stressed out the theories about the pineal organ before Descartes [6–11]. The first comprehensive descriptions of the pineal gland are found in Galen's *On the usefulness of the parts of the body, eight book* [12]. Galen (ca 130–210) named it pineal (*kônarion* in greek, *glandula pinealis* in latin) because of its particular shape resembling a pine cone (*kônos*, *pinus pinea*). At that time, a gland was considered to have a purely mechanical support role to vessels particularly veins:

Coming back, then, to the subject of the parts behind the middle [third] ventricle, let us examine the body [the pineal body] which lies at the beginning of the canal connecting the middle ventricle with the posterior encephalon and which is called conarium [little pine cone] by those versed in anatomy, to see for what usefulness it was formed. This body is a gland to judge by its substance, but in shape it very closely resembles a pine cone, and from this it takes its name.

Pages 419–420 [12]

To better understand Galen's notion of the pineal gland, we must remind his physiology and particularly his conception of the nervous system. Based upon a classical Hippocratic tradition, Galen defines health as an equilibrium between the four bodily humors: the blood, the yellow bile, the dark bile, and the phlegm. These four fluids are composed of a mixture of the four fundamental elements associated to their respective qualities: fire/hot, water/humid, air/cold, and terra/dry. According to Galen, human temperaments result from the combination and the dosage of these elements. In the brain, he considered two lateral ventricles as a unique cavity forming the anterior ventricle, a middle ventricle (3rd

ventricle) and a posterior ventricle (4th ventricle). He described the ventricles filled with a volatile airy substance he named the *psychic pneuma*, intimately linked to the substance of the soul, i.e. the *sensus communis* [13].

Before Galen, the pineal gland was described as a purely mechanical valve, such as the pylori between the stomach and the duodenum, regulating the flow of the *psychic pneuma* between the middle ventricle (3rd ventricle) and the posterior one (4th ventricle). Galen pointed out this misconception [13]:

Some think it has the same usefulness as the pylorus of the stomach; for they say that the pylorus too is a gland and prevents the nutriment from being taken over from the stomach into the thin intestine before it is concocted, and that this gland, the pineal body, standing at the beginning of the canal that transmits the pneuma from the middle [third] ventricle to the one in the parencephalis [fourth ventricle] is a guardian and housekeeper, as it were, regulating the quantity that is transmitted.

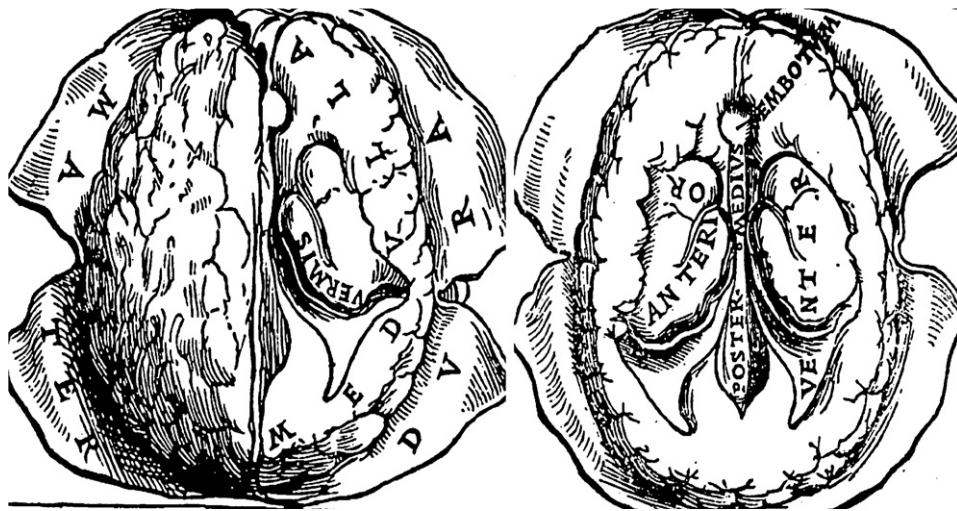
Galen argued his rejection of the ancient pineal theory on the anatomical data he collected during his experience as physician of gladiators having examined dozens of cranio-cerebral injuries but also on dissections of pigs and monkeys. By this way, he described the venous complex surrounding the pineal gland, known nowadays as vein of Galen:

I, myself, however, have told earlier what opinion we should hold concerning the pylorus of the stomach, and I believe that this gland resembling a pine cone and filling up the bifurcation of the large vein [vein cerebri magna] from which nearly all the choroid plexuses of the anterior ventricles arise was formed for the same usefulness as other glands that support veins as they divide. . .

According to him, the pineal gland cannot regulate the flow of *psychic pneuma* between the middle and posterior ventricles because the gland is situated outside the brain. He explained that the pineal gland does not have any possibility of movement because of its morphology. As a possible valve to regulate the flow of *psychic pneuma*, he rather proposed the cerebellar vermis he named *vermicular appendix*:

The notion that the pineal body is what regulates the passage of the pneuma is the opinion of those who are ignorant of the action of the vermiform epiphysis [vermis superior cerebelli] and who give more than due credit to the gland. Now if the pineal body was a part of the encephalon itself, as the pylorus is part of the stomach, its favorable location would enable it alternately to open and close the canal because it would move in harmony with the contractions and expansions of the encephalon. Since this gland, however, is by no means a part of the encephalon and is attached not to the inside but to the outside of the ventricle, how could it, having no motion of its own, have so great an effect on the canal? . . . Why need I mention how ignorant and stupid these opinions are?

Since Galen, many assumptions on the role of the cerebral ventricles and particularly the mechanisms of regulation of the *psychic pneuma's* flow have been imagined. During the second half of the 4th century, Posidonius of Bysance theorized a ventricular somatotopy placing the imagination in the anterior ventricle, the reason in the middle one, and the memory in the posterior ventricle. A Lebanese physician, Qusta Ibn Luca (864–923) applied Galen's idea of the vermicular appendix to the ventricular somatotopy described by Posidonius of Bysance: by raising the head and opening the vermicular appendix, one allows the access to the posterior ventricle where memory is stocked, while by bending down the head, souvenirs are isolated in the posterior ventricle and one can concentrate to have clear unpolluted ideas [13]. During the middle



**Fig. 1.** Berengario da Carpi conception (16th century) similar to Mondino De Luzzi one in which the choroid plexuses of the lateral ventricles (left picture) are confounded with cerebellar vermis initially described by Galen and are supposed to play the role of a worm-like appendix regulating the psychic pneuma flow between anterior and median ventricles (right picture).

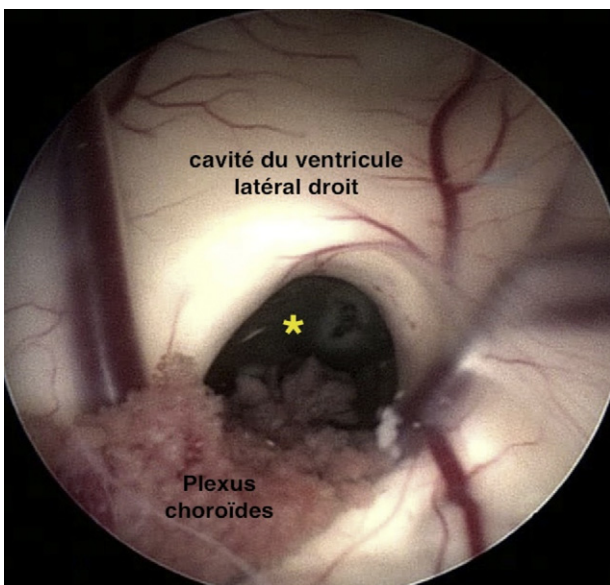
age, much confusion about the nature of this vermicular appendix appeared, from the pineal gland to the cerebellar vermis or even the choroid plexus (Figs. 1–3). All these misconceptions were definitely disqualified during the Renaissance with the anatomical works of Vesalius [4] and Caspar Bauhin [5] (Figs. 4 and 5). During the same period, Niccolo Massa [14] demonstrated the existence of the cerebrospinal fluid filling the brain ventricles, and the *psychic pneuma's* theory became obsolete. From a purely chronological point of view, how can we imagine that Descartes did not know about the core anatomical works of Vesalius (1543) and Caspar Bauhin (1605)? How can we explain the obvious anatomical approximations of Descartes concerning the position and the role of the pineal gland, which constitutes the support of his dualistic philosophy?

**3. The cartesian neurophysiology**

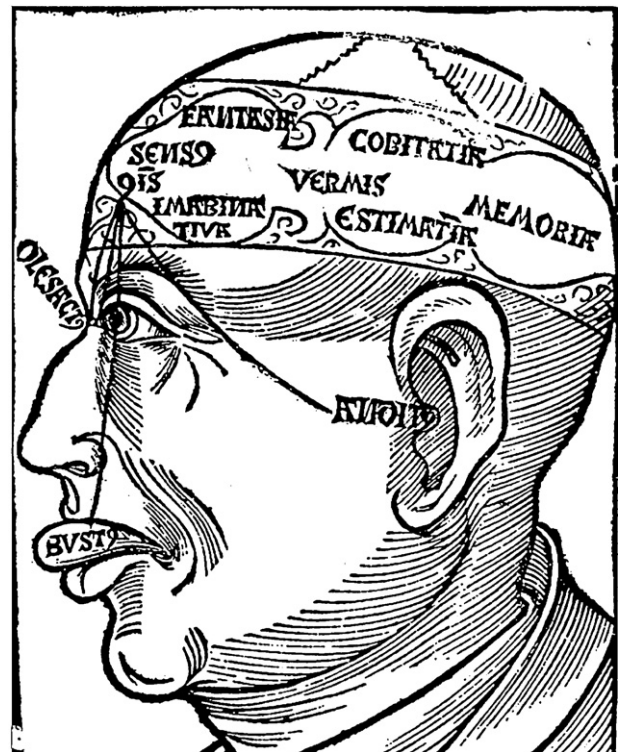
The dualistic philosophy of Descartes relies on a clear-cut distinction between the mental substance (*Res cogitans*) and the

corporeal one (*Res extensa*). He emphasizes also on three notions: the soul, the body, and their substantial union. In the 5th part of the *Discourse on the Method* [3], Descartes defines the “real man” as a result of the substantial union:

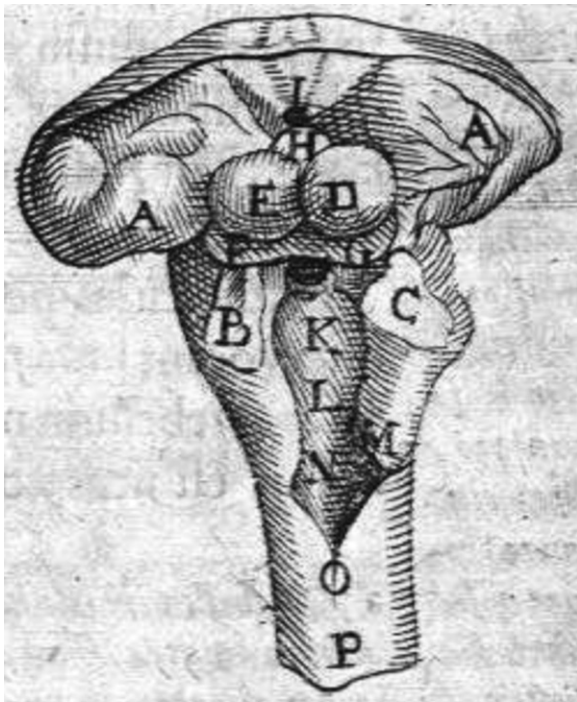
After that, I described the rational soul, and showed that, unlike the other things of which I had spoken, it cannot be derived in any way from the potentiality of matter, but must be specially created. And I showed how it is not sufficient for it to be lodged



**Fig. 2.** Endoscopic view of the right Monro foramen, communication between the right lateral ventricle (anterior ventricle) and the third ventricle (median ventricle). This foramen is boarded by the choroid plexuses considered as the worm-like vermicular appendix in Mondino dei Luzzi's conception.



**Fig. 3.** Medieval theory of ventricular localizations: gustative (gustus), olfactory (olfactus) and auditory (auditus) functions are related to the common sense (sensus communis) located in the anterior ventricle as well as imagination and fantasy. The vermis, either cerebellar or choroid plexus depending on author, is supposed to regulates the flow of spirit animals between anterior and middle ventricles. In Hieronymus Brunschwig, *The noble experience of the virtuous handy warke of surgery*, Londres, 1525 (1st german edition 1497).



**Fig. 4.** Posterior view of the brainstem and 3rd ventricle. The pineal gland (H) is obviously represented outside the cerebral ventricles, on the external surface of the brain above the quadrigeminal plate (E and D). In Bauhin Gaspard. *Theatrum Anatomicum*. Frankfurt am Main, Typis Matthaei Beckeri P.601 (1605).

in the human body like a helmsman in his ship, except perhaps to move its limbs, but that it must be more closely joined and united with the body in order to have, besides this power of movement, feelings and appetites like ours and so constitute a real man.

Discourse on the method. Part five – page 141, vol. 1 [3]

### 3.1. The neuroanatomical corpus of René Descartes

Which neuroanatomical knowledge Descartes had used as a support to his dualistic conception of the substantial union? The

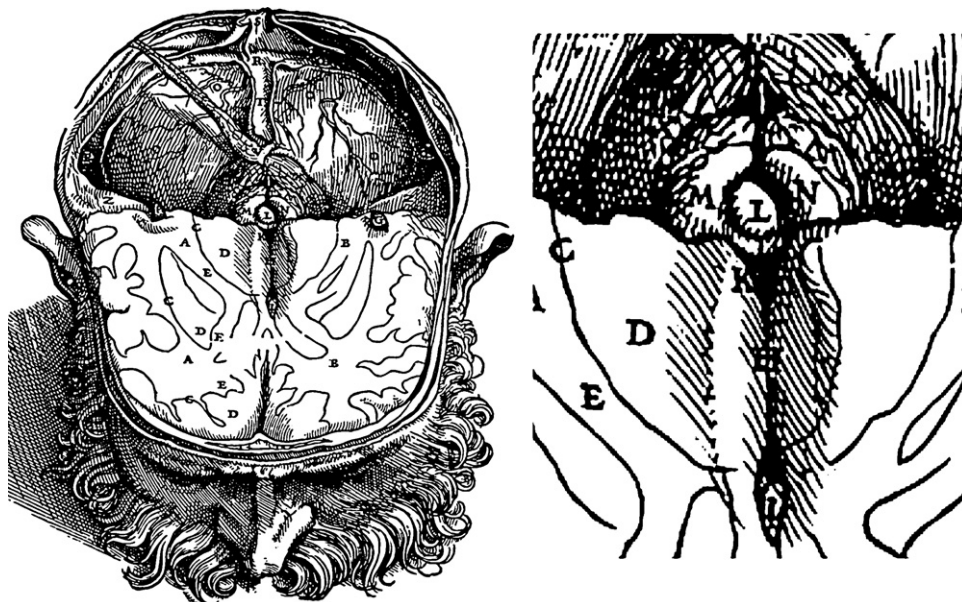
Cartesian anatomy and particularly the one concerning the brain are spread in many of his writings, but predominantly in *Excerpta Anatomica*, which he wrote between 1631 and 1648 (Fig. 6). He considered three parts in the brain: the external layer (corresponding to the cerebral cortex as we know it nowadays), the internal layer or inner surface of the cerebral ventricles (ependyma), and the brain substance in between them (white matter). According to him, the inner surface is composed of a complex network with innumerable pores boarded by walls corresponding to the origin of the nerves (Fig. 7). Descartes distinguishes short nerves reaching the small pial cortical vessels and long nerves converging towards the skull base to constitute the spinal cord which distributes later to the limbs and trunk. These hollow nerves are filled with animal spirits, and support both sensitive and motor influxes.

Now, the substance of the brain being soft and pliant, its cavities would be very narrow and almost all closed (as they appear in the brain of a corpse) if no spirits entered them. But the source which produces these spirits is usually so abundant that they enter these cavities in sufficient quantity to have the force to push out against the surrounding matter and make it expand, thus tightening all the tiny nerve-fibres which come from it.

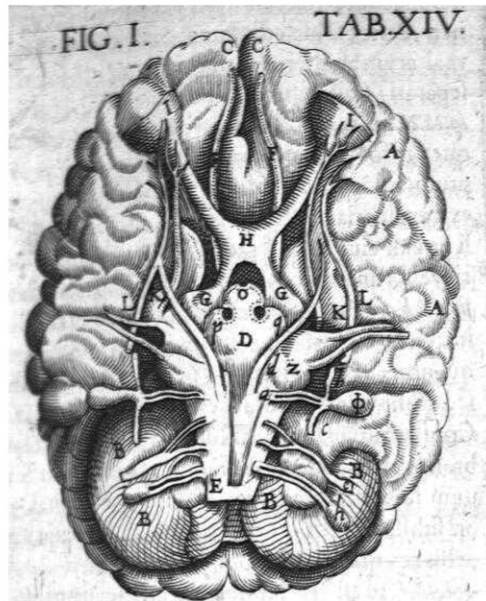
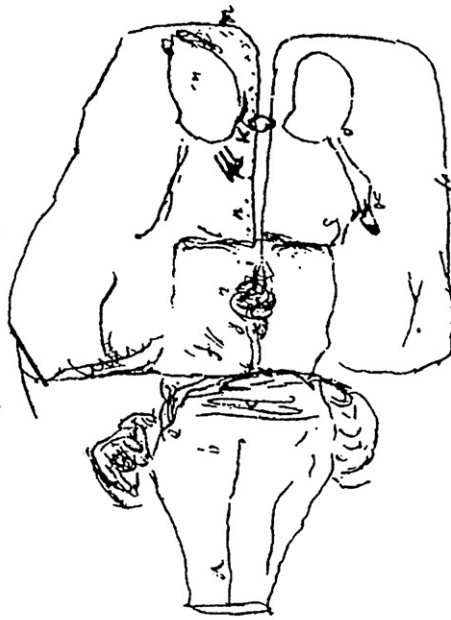
Treatise on man. Page 104, vol. 1 [3]

Particularly between 1629 and 1632, period during which he wrote his *Treatise on man*, Descartes used to assist sheep dissections at his Amsterdam's butcher shop [15]. Descartes dissected by himself sheep's brains and illustrated his findings [16]. In his correspondence with Mersenne [2], Descartes emphasized on the importance of anatomical dissections in the understanding of the brain processes such as memory and imagination, and in the same time he confirmed his knowledge of the academic anatomical works of Vesalius and Caspar Bauhin [17]. In the same correspondences, Descartes detailed some of his dissections and why he did choose fresh sheep brains because of the alterations of brain tissues observed post-mortem [2]:

I would not find it strange that the gland called the conarium should be found decayed when the bodies of lethargic persons are dissected, because it decays very rapidly in all other cases too. Three years ago at Leiden, when I wanted to see it in a woman who was being autopsied, I found it impossible to



**Fig. 5.** In the second edition of Vesale's book (1555), the pineal gland is more clearly represented outside the ventricular cavities (L) just above the anterior quadrigeminal tubercles (M and N) and posterior to the third ventricle cavity (K).



**Fig. 6.** Left: Descartes. *Excerpta Anatomica*. Inferior view of the brain and anterior view of the brainstem. The approximate style of the drawings make an obvious contrast with those of de La Forge and van Gutschoven illustrating *De Homine*, but also contrasting with the academic and rigorous style of Vesale or Gaspard Bauhin even if Descartes was already aware of their works. Right: same inferior view of the brain by Gaspard Bauhin. *Theatrum Anatomicum*. Frankfurt am Main, Typis Matthaei Beckeri P.601 (1605).

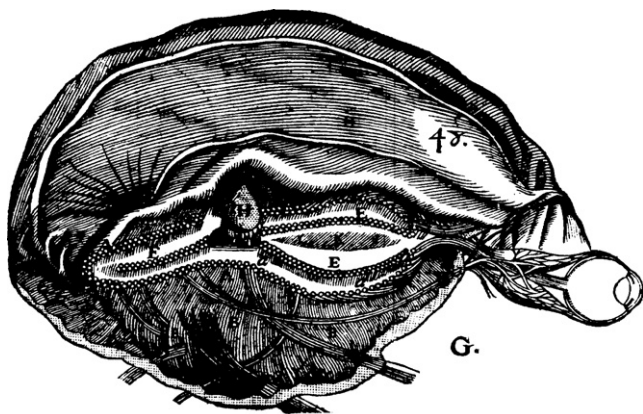
recognize it, even though I looked very thoroughly, and knew well where it should be, being accustomed to find it without any difficulty in freshly killed animals. An old professor who was performing the autopsy, named Valcher, admitted to me that he had never been able to see it in any human body. I think this is because they usually spend some days looking at the intestines and other parts before opening the head.

I need no proof of the mobility of this gland apart from its situation; for since it is supported only by the little arteries which surround it, it is certain that very little will suffice to move it. But for all that I do not think that it can go far one way or the other. . .

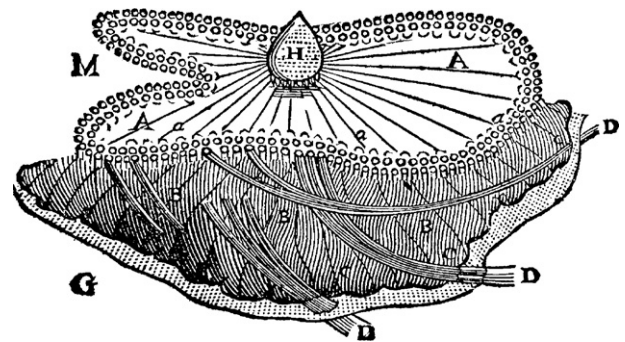
To Mersenne. 1 April 1640 – page 146, vol. 3 [2]

It is very likely that Descartes knew about the extra-ventricular position of the pineal gland and thus its supposed capacity of regu-

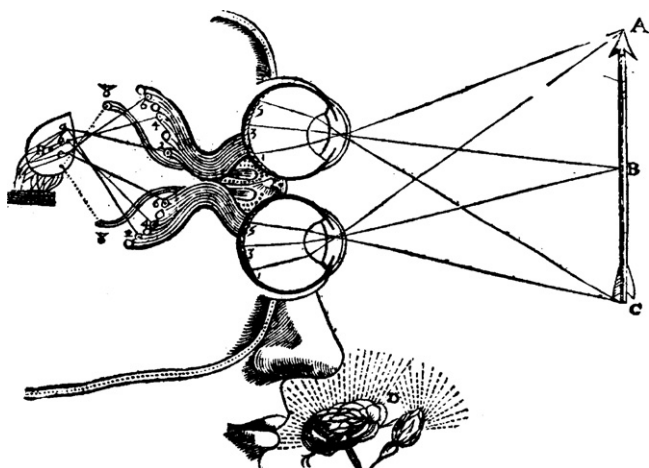
lating the flow of animal spirits within the cerebral ventricles. It is important to point out that the illustrations in the *Treatise of man* have been made by de La Forge and van Gutschoven after Descartes' death (Fig. 8), leaving a margin to the interpretation of Descartes' writings. De La Forge, a medical doctor, explained in his remarks at the end of the *Treatise of man* (Clerselier's preface of the edition of 1664) that his anatomical drawings result more from an intelligible process rather than an authentic anatomical representation of reality. For example, de La Forge confessed that he represented the pineal gland in his illustrations larger than it should be because of its central role in Descartes' philosophy. Descartes' anatomical conception has certainly been influenced by his Jesuitical education as well as the neurophysiological legacy of Erasistrate. This latter already developed the idea of hollow tubular nerves full of air and converging toward the brain, inspiring obviously Descartes' conception despite the wide diffusion of Vesalius' works in occidental Europe. The originality of Descartes' theory lays on his mechanistic conception of the man-machine assigning the seat of soul to the pineal gland. Therefore, de La Forge and van Gutschoven's illustrations in *The treatise of man* should be definitely considered as



**Fig. 7.** The pineal gland (H) occupies the middle of the ventricles in Descartes' conception. According to the latter, the inner surface of the cerebral ventricles (E) is lined with numerous very small pores leading to hollow nervous tubes. The pineal organ is therefore playing the role of an orchestra conductor regulating the flow of animal spirits as well as memory, imagination, sensations and even nociceptive reflexes. In this posthumous publication of Descartes, two physicians did the illustrations, La Forge (F) and van Gutschoven (G on the illustrations). Page 63, *De Homine*.



**Fig. 8.** Central position of the pineal organ within the cerebral ventricles. A very rich vascular network supports the pineal gland. We can retrieve the brain anatomy according to Descartes with the porous architecture of the inner surface of brain and the initial centimeters of the nerves originating from these pores. Van Gutschoven's illustration in *De Homine*.



**Fig. 9.** The pineal gland plays a role in the immediate treatment and memorization of stimulations either visual or olfactory ones. Only one image is produced on the surface of the pineal gland from a binocular vision. We can also remark the mobile ability the pineal gland has. *De Homine*.

theoretical conceptions rather than an academic neuroanatomical work (Figs. 9 and 10).

### 3.2. The pineal organ as the substratum of the soul–body union

More than a physical seat of soul, Descartes considered the pineal gland as the place where the soul (*Res cogitans*) and the body (*Res extensa*) interact, similar to a substantial interface:

First I consider that there are in us certain primitive notions which are as it were the patterns on the basis of which we form all our other conceptions. There are very few such notions. First, there are the most general- those of being, number, duration, etc.- which apply to everything we can conceive. Then as regards body in particular, we have only the notion of extension, which entails the notions of shape and motion; and as regards the soul on its own, we have only the notion of thought, which includes

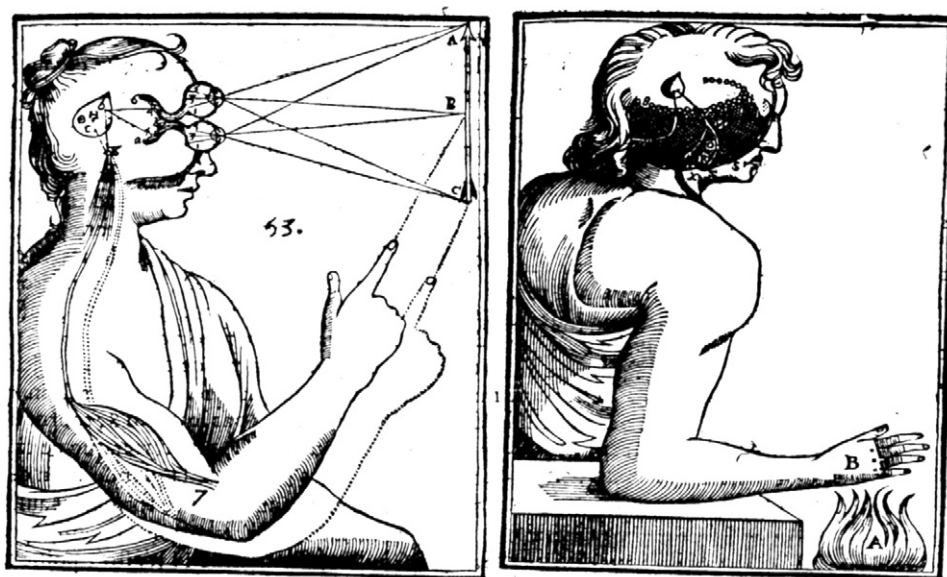
the perceptions of the intellect and the inclinations of the will. Lastly, as regards the soul and the body together, we have only the notion of their union, on which depends our notion of the soul's power to move the body, and the body's power to act on the soul and cause its sensations and passions.

I observe next that all human knowledge consists solely in clearly distinguishing these notions and attaching each of them only to the things to which it pertains. For if we try to solve a problem by means of a notion that does not pertain to it, we cannot help going wrong. Similarly we go wrong if we try to explain one of these notions by another, for since they are primitive notions, each of them can be understood only through itself.

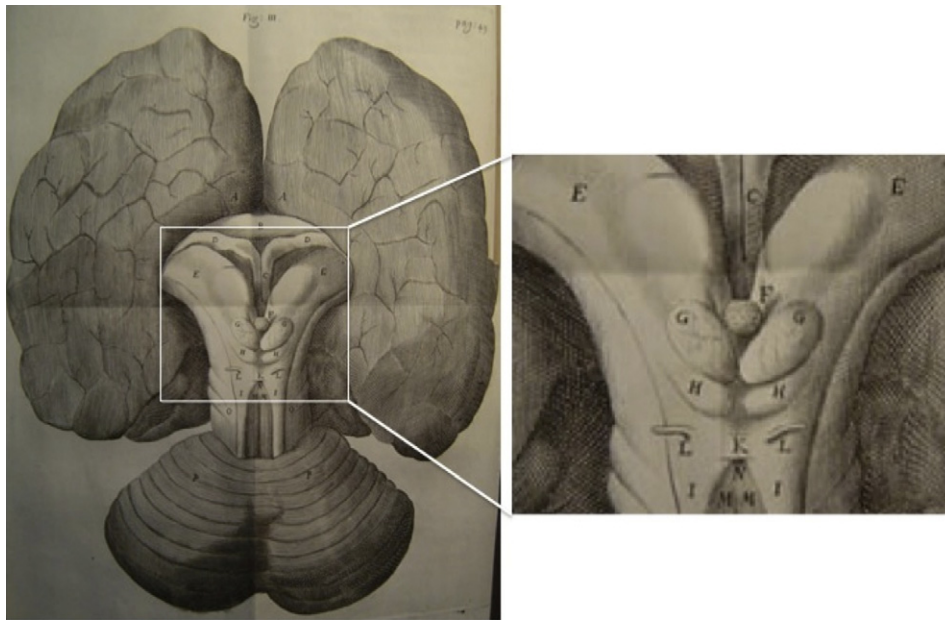
To Princess Elizabeth. 21 May 1643 – page 218, vol. 3 [2]

The question of interaction of the soul and the body is specifically addressed in his letter to Princess Elisabeth of May the 21st, 1643 [2]. In her mails, Elisabeth raised the particular question of immeasurability of both notions i.e. between intellectual (imagination, memory, thoughts, sensibilities, audition) and bodily acts (mainly motility). The question of why Descartes specifically chose the pineal gland to play the role of seat of soul is not clearly answerable. He primarily exposed his pineal thesis in several correspondences in the 1640's but also in his *Treatise of man* (written in 1637 and published in 1662). He based his choice mainly because he thought that the pineal gland is the sole organ in the brain that is odd. He considered that if we perceive a unique image coming from two eyes, there should be a core cerebral structure where the sensorial data originating from pair receptors are gathered before being managed by the soul. He stated that the pineal gland was the only odd organ of the brain and its central position within the cerebral cavities as well as its rich surrounding arterial network justifies its role in regulating the flow of animal spirits. Descartes refuted the possible role of the pituitary gland by the fact that it is out of the brain substance confined within the sphenoid bone (sella turcica) and it is immobile:

The difficulty you raise about the conarium seems to be the most urgent, and the man who wants to defend publicly what I said about it in my Optics does me so much honour that I must try to answer his queries (Dr. Villiers of Sens). So without waiting



**Fig. 10.** Left: In Descartes' neurophysiology, the pineal gland plays a key role in the coordination of the eye movements and vision. The transmission of data is produced by the mechanical strength of the nervous tubes and the increase of the animal spirits within. *Méditations métaphysiques* (1641). Right: the nociceptive reflex is exclusively based on mechanical shortening of the nerve transmitting thus the information directly to the pineal organ without any spinal cord connection. By its movements, the pineal gland will lead to modifications in animal spirits flow and therefore generates a mechanical muscular retraction reflex. *De Homine* (1664).



**Fig. 11.** Posterior view of the brainstem showing the pineal gland (F) outside the ventricle cavities above quadrijeminal tubercles (G and H). Thomas Willis. *Cerebri Anatomie: cui accessit nervorum descriptio et usus*. London, 1664.

for the next post I will say that the pituitary gland bears some relation to the pineal gland in that both are situated between the carotid arteries and on the path which the spirits take in rising from the heart to the brain. But this gives no ground to suspect that the two have the same function; for the pituitary gland is not, like the pineal gland, in the brain, but beneath it and entirely separate, in a concavity of the sphenoid bone specially made to take it, and even beneath the dura mater if I remember correctly. Moreover, it is entirely immobile, whereas we experience, when we imagine, that the seat of the common sense, that is to say the part of the brain in which the soul performs all its principal operations, must be mobile. It is not surprising that the pituitary gland should be situated where it is, between the heart and the conarium, because many little arteries come together there to form the carotid plexus, without reaching the brain. For it is almost a general rule throughout the body that there are glands at the meeting points of large numbers of branches of veins or arteries. It is not surprising either that the carotids send many branches to that point: that is necessary to nourish the bones and other parts, and also to separate the coarser parts of the blood from the more rarefied parts which alone travel through the straightest branches of the carotids to reach the interior of the brain, where the conarium is located. . . There is good reason for the conarium to be like a gland, because the main function of every gland is to take in the most rarefied parts of the blood which are given off by the surrounding vessels, and the function of the conarium is to take in the animal spirits in the same manner. Since it is the only solid part in the whole brain which is single, it must necessarily be the seat of the common sense, i.e. of thought, and consequently of the soul; for one cannot be separated from the other.

To Mersenne. 24 December 1640 – page 162, vol. 3 [2]

In the same way he disqualified the cerebellar vermis because according to him it was the result of the union of two hemivermises.

How Descartes conceived the role of a pineal transducer in his man-machine? One may be disconcerted by the presence of a clear contradiction in *The passions of the soul* because of the presence of

many Augustinian references to the presence of the soul in all the parts of the body:

We need to recognize also that although the soul is joined to the whole body, nevertheless there is a certain part of the body where it exercises its functions more particularly than in all the others. It is commonly held that this part is the brain, or perhaps the heart—the brain because the sense organs are related to it, and the heart because we feel the passions as if they were in it. But on carefully examining the matter I think I have clearly established that the part of the body in which the soul directly exercises its functions is not the heart at all, or the whole of the brain. It is rather the innermost part of the brain, which is a certain very small gland situated in the middle of the brain's substance and suspended above the passage through which the spirits in the brain's anterior cavities communicate with those in its posterior cavities. The slightest movements on the part of this gland may alter very greatly the course of these spirits and conversely any change, however slight, taking place in the course of these spirits may do much to change the movements of the gland.

The passions of the soul – page 340, vol. 1 [3]

Through his rationalist and mechanistic methodology, Descartes based the transducer role of the pineal gland mainly on the regulation of the animal spirit's flow in the cerebral ventricles. He imagined hollow nerves coming from all the organs and converging to the brain ventricles, filled of animal spirits. These nerves transmit the peripheral information (skin, muscles, articulations, . . .) by a mechanical mode (stretching) to the intraventricular animal spirits, producing therefore an image on the surface of the pineal gland. In the *Metaphysical meditations* [18], Descartes sketched a theory on the nociceptive reflex based exclusively on a mechanical plan leading finally to the pineal gland, excluding any role of the spinal cord (Fig. 10).

Descartes' theory on the pineal gland inspired at least two medical theses in 1641 (Jean Cousin in Paris and Regius in Utrecht). Several historians have questioned the originality of Descartes' theory at the beginning of the 20th century (Jules Soury, Béla Révész, Pierre Mesnard) [6]. Descartes defended his theory with

some contemporary physicians through his correspondences with Mersenne:

The letter of the learned doctor (Christophe Villiers de Sens, 1595–1661) contains no argument to refute what I have said about the gland called the conarium (pineal gland) except that it can suffer alteration like the rest of the brain. This is no reason why it should not be the principal seat of soul; for it is certain that the soul must be joined to some part of the body, and there is no other part which is not as much or more subject to alteration than this gland. Although it is very small and very soft, it is situated in such a well-protected place that it is almost immune from illness, like the vitreous or crystalline humour of the eye. It happens much more often that people become troubled in their minds without any known cause – which could be attributed to some malady of this gland – than it happens that sight is lost through a malady of the crystalline humour. . .

He says that the soul can utilize double parts, or use the spirits, which cannot all reside in this gland. I agree, because I do not think that the soul is so imprisoned in the gland that it cannot act elsewhere. But utilizing a thing is not the same as being immediately joined or united to it; and since our soul is not double, but single and indivisible, it seems to me that the part of the body to which it is most immediately joined should also be single and not divided into a pair of similar parts. I cannot find such a part in the whole brain except this gland. . .

To Mersenne. 30 July 1940 – Page 149, vol. 3 [2]

#### 4. Reactions to Descartes' theory

Critics of Descartes' theory on the pineal gland as the seat of soul have been numerous ranging from neuroanatomical critics to more metaphysical and theological ones. The originality of Descartes' theory relies mainly on the mathematization and mechanization of his dualistic philosophy in the man-machine, with an obvious endeavor to conciliate two immeasurable notions. Lopez-Munoz et al. described the evolution of Cartesian theory through the centuries, and particularly its influence on the scientific movements of the 18th century [10].

##### 4.1. Neuroanatomical critics

Many evident neuroanatomical approximations are found in the *Treatise of man*. Descartes wrote this book in 1637 but was published only posthumous in 1662 (Schuyll's edition) and in 1664 (Clerselier's edition). According to his numerous correspondences [2], we know that Descartes was aware of the anatomical works of Galen, Vesalius and Caspar Bauhin. Already Galen demonstrated the position of the pineal gland outside the cerebral ventricles and described the rich network of veins surrounding the gland. Otherwise, Descartes described the genesis of the animal spirits in the digestive tract, the liver, the lungs and the heart and their path up to the *rete mirabile*, an arterial network of the skull base in which a selection of the finest particles of the animal spirits is performed:

The parts of the blood which penetrate as far as the brain serve not only to nourish and sustain its substance, but also and primarily to produce in it a certain very fine wind, or rather a very lively and pure flame, which is called the animal spirits. For it must be noted that the arteries which carry blood to the brain from the heart, after dividing into countless tiny branches which make up the minute tissues that are stretched like tapestries at the bottom of the cavities of the brain, come together again around a certain little gland situated near the middle of the substance of the brain, right at the entrance to its cavities. The arteries in this region have a great many little

holes through which the finer parts of the blood can flow into this gland. . . These parts of the blood, without any preparation or alteration except for their separation from the coarser parts and their retention of their extreme rapidity which the heat of the heart has given them, cease to have the form of blood, and are called the animal spirit.

Treatise of man. Page 100, vol 1 [3].

The airy and volatile content of the cerebral ventricles as described by Descartes is totally obsolete while Nicollo Massa [14] described the cerebrospinal fluid in 1536, one century before the writing of the *Treatise of man*. Between 1664 and 1669, many debates took place regarding the brain anatomy, particularly illustrated through the works of Thomas Willis (Fig. 11) in his *De cerebri anatome* (1664) and Niels Stensen (Nicolas Steno) in the *Lecture on the anatomy of the brain* (1669) [10]. In this latter, Stensen provided a systematic critics of Descartes' theory on the pineal gland based purely on objective anatomical facts. Stensen's anatomical critics were later misused by others to question Descartes' dualism, while Stensen himself looked at Descartes neuroanatomical theory as a theoretical and conceptual construction provided as a support to his dualistic philosophy and not as a descriptive anatomical work [19]:

I should have been prevented from referring to the faults in this treatise by the respect that I feel is owed by everyone, myself included, to intellects of this order (Descartes, Vesalius), I would have been pleased to admire it, with the rest, as a description of a beautiful machine, invented entirely by him, if I had not met many persons who take it as quite the opposite and who wish to pass it off as a faithful representation of what lies hidden in the compartments of the human body.

Lecture on the anatomy of the brain. Pages 128–131 [19]

In the first part of his *Lecture on the anatomy of the brain*, Stensen defended the rationalist methodology of Descartes, understanding that the neuroanatomical pineal theory is rather a conceptual support to the dualistic philosophy. Later, Spinoza used Stensen's critics of Descartes' anatomy to discredit the dualism. Stensen defended Descartes' anatomical approximations invoking the lack of a specific education to anatomical dissections as well as the absence of ad hoc anatomical laboratories at that time [19]:

There is no need, therefore, to condemn Monsieur Descartes if his system of the brain is not wholly in conformity with experience. The excellence of his mind, apparent chiefly in his "Treatise of Man", makes amends for the errors in his hypotheses. We note that very skilful anatomists, such as Vesalius and others, have made similar mistakes. If these great men, who passed the better part of their lives in dissection, have been pardoned for these faults, why should be less indulgent with respect to M. Descartes, who has spent his time very happily in other speculations?

Lecture on the anatomy of the brain. Pages 128–131 [19]

Stensen gave precise anatomical objections to Descartes' observations concerning mainly the position of the pineal organ outside the cerebral ventricles, and therefore its ability to regulate the flow of animal spirits:

But the posterior part, namely one half of the gland, is so much outwith the cavities that onlookers may be satisfied very easily on this point—for that one need only remove the cerebellum, or small brain, and one of the third pair of tubercles, or both if you wish, without touching the ventricles, having done this skillfully, you will observe the posterior part of the gland, quite exposed, without any visible passage by which air or other fluid might enter the ventricles.

Lecture on the anatomy of the brain. Pages 128–131 [19]



Stensen objected in the same way the faculty of motility of the pineal gland as imagined by Descartes:

Regarding M. Descartes' statements, that the gland can support actions by becoming inclined sometimes to one side, sometimes to the other, experience assures us that it is, in fact, incapable of doing so, for it is obvious that it is so entangled among all the parts of the brain and so well attached to these parts on all sides, that you would no know how to give it the least movement without violence and without breaking the fibers that hold it attached. It is easy to show that its situation is contrary to what M. Descartes describes for us, for it is not perpendicular to the brain nor it is inclined forward, as many experienced anatomists believe, but its point, at all times, faces the cerebellum, or small brain, and makes an angle with the base of approximately forty-five degrees.

Lecture on the anatomy of the brain. Pages 128–131 [19]

Finally, Stensen demonstrated that the arterial network surrounding the pineal gland as stated by Descartes was a venous one as described by Galen therefore questioning the mechanism of filtration of the animal spirits:

Nor is it any more true that there is a connection between the gland and the brain by means of arteries, for the whole base of the gland adheres to the substance of the brain. . .

The hypothesis that the arteries are gathered around the gland, rising towards the great euripus, is a matter of some consequence in M. Descartes' system since the separation and motion of the spirits depend on it. Nevertheless, if you believe your eyes, you will find only an assembly of veins coming from the corpus callosum, from the interior substance of the brain, from the plexus choroides, from various parts of the base of the brain and from the gland itself, you will find that these are veins and not arteries, that they carry blood from the heart to the brain.

Lecture on the anatomy of the brain. Pages 128–131 [19]

Through his *Lecture on the anatomy of the brain*, Stensen proposed a new methodology for anatomical dissections and the creation of adapted laboratory structures for this purpose to produce academic works:

We shall always be miserably ignorant if we are satisfied by the scraps of information that they have left to us and if men most suited to research work fail to combine their labours, their industry and their studies to come to some knowledge of the truth that should be the principal end of those who reason and study in good faith.

Lecture on the anatomy of the brain. Page 154 [19]

#### 4.2. Metaphysical and theological critics

In the *Théodicée*, Leibniz was inspired by astronomical models and proposed 3 possible explanations to the interaction between the soul and the body using an analogy with 2 clocks [20]. To be perfectly synchronous, these clocks may interact directly (immediate action of a substance on another one based upon a scholastic inspiration), or may be perpetually managed a posteriori by an alert watchmaker (occasionalism involving a creator who continuously modulates the behavior of one substance according to the second one), or may be ideally a priori elaborated. Elsewhere, in the 5th part of the preface of *The Ethics*, Spinoza in a monist posture gives an accurate critic of the neuroanatomical Cartesian description of the pineal gland, and therefore questioned clearly the notion of a seat of soul [21]:

For he maintained, that the soul or mind is specially united to a particular part of the brain, namely, to that part called the pineal gland, by the aid of which the mind is enabled to feel

all the movements which are set going in the body, and also external objects, and which the mind by a simple act of volition can put in motion in various ways. He asserted, that this gland is so suspended in the midst of the brain, that it could be moved by the slightest motion of the animal spirits: further, that this gland is suspended in the midst of the brain in as many different manners, as the animal spirits can impinge thereon; and, again, that as many different marks are impressed on the said gland, as there are different external objects which impel the animal spirits towards it; whence it follows, that if the will of the soul suspends the gland in a position, wherein it has already been suspended once before by the animal spirits driven in one way or another, the gland in its turn reacts on the said spirits, driving and determining them to the condition wherein they were, when repulsed before by a similar position of the gland. He further asserted, that every act of mental volition is united in nature to a certain given motion of the gland. For instance, whenever anyone desires to look at a remote object, the act of volition causes the pupil of the eye to dilate, whereas, if the person in question had only thought of the dilatation of the pupil, the mere wish to dilate it would not have brought about the result, inasmuch as the motion of the gland, which serves to impel the animal spirits towards the optic nerve in a way which would dilate or contract the pupil, is not associated in nature with the wish to dilate or contract the pupil, but with the wish to look at remote or very near objects. Lastly, he maintained that, although every motion of the aforesaid gland seems to have been united by nature to one particular thought out of the whole number of our thoughts from the very beginning of our life, yet it can nevertheless become through habituation associated with other thoughts; this he endeavours to prove in the *Passions de l'âme*, I. 50. He thence concludes, that there is no soul so weak, that it cannot, under proper direction, acquire absolute power over its passions. For passions as defined by him are "perceptions, or feelings, or disturbances of the soul, which are referred to the soul as species, and which (mark the expression) are produced, preserved, and strengthened through some movement of the spirits." (*Passions de l'âme*, I. 27.) But, seeing that we can join any motion of the gland, or consequently of the spirits, to any volition, the determination of the will depends entirely on our own powers; if, therefore, we determine our will with sure and firm decisions in the direction to which we wish our actions to tend, and associate the motions of the passions which we wish to acquire with the said decisions, we shall acquire an absolute dominion over our passions.

In the same text, Spinoza criticized clearly the methods used by Descartes in his description of his theory on the pineal gland, balancing it with the rationalist methodology that Descartes used in other of his works [21–23]:

Such is the doctrine of this illustrious philosopher (in so far as I gather it from his own words); it is one which, had it been less ingenious, I could hardly believe to have proceeded from so great a man. Indeed, I am lost in wonder, that a philosopher, who had stoutly asserted, that he would draw no conclusions which do not follow from self-evident premises, and would affirm nothing which he did not clearly and distinctly perceive, and who had so often taken to task the scholastics for wishing to explain obscurities through occult qualities, could maintain a hypothesis, beside which occult qualities are commonplace.

Spinoza developed his monism in a clear-cut contrast with the Cartesian dualism, particularly emphasizing on the role of God and disqualifying point by point the role of the pineal gland as a seat of soul:

What does he understand, I ask, by the union of the mind and the body? What clear and distinct conception has he got of thought in most intimate union with a certain particle of extended matter? Truly I should like him to explain this union through its proximate cause. What clear and distinct conception has he got of thought in most intimate union with a certain particle of extended matter? What clear and distinct conception has he got of thought in most intimate union with a certain particle of extended matter? But he had so distinct a conception of mind being distinct from body, that he could not assign any particular cause of the union between the two, or of the mind itself, but was obliged to have recourse to the cause of the whole universe, that is to God. Further, I should much like to know, what degree of motion the mind can impart to this pineal gland, and with what force can it hold it suspended? For I am in ignorance, whether this gland can be agitated more slowly or more quickly by the mind than by the animal spirits, and whether the motions of the passions, which we have closely united with firm decisions, cannot be again disjoined therefrom by physical causes; in which case it would follow that, although the mind firmly intended to face a given danger, and had united to this decision the motions of boldness, yet at the sight of the danger the gland might become suspended in a way, which would preclude the mind thinking of anything except running away. In truth, as there is no common standard of volition and motion, so is there no comparison possible between the powers of the mind and the power or strength of the body; consequently the strength of one cannot in any wise be determined by the strength of the other. We may also add, that there is no gland discoverable in the midst of the brain, so placed that it can thus easily be set in motion in so many ways, and also that all the nerves are not prolonged so far as the cavities of the brain.

Nicolas Malebranche (1638–1715) defended the notion of a seat of soul even if he admitted the neuroanatomical errors of Descartes concerning the position and the role of the pineal gland. Even if he adopted Descartes' dualism, Malebranche insisted on the necessary intervention of a Creator on the transduction soul/body [24].

## 5. Conclusion

The dualistic metaphysics of René Descartes, based on the distinction of two substances and their interaction, still raises the contemporary question of the complex interaction between the soul and the body. By pointing out Descartes' anatomical approximations, we investigated the resulting critics to the soul/body pineal theory through both a purely neuroanatomical perspective but also a metaphysical one. We therefore believe that Descartes' neuroanatomical errors were intentional and do not result from Descartes' lack of knowledge. It seems that Descartes adapted his original neurophysiological concept to his metaphysical dualistic theory. The last two decades saw the resurgence of the question of the union of the soul and the body, in the light of modern functional neuroimaging. There is a current global trend toward a scientific monism.

## Conflict of interest

None.

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