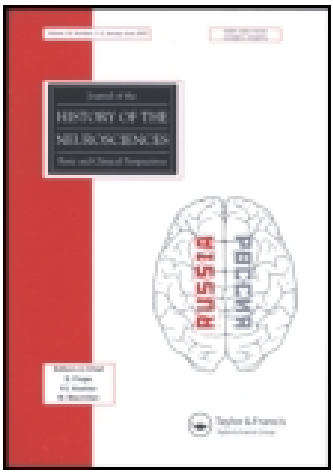

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Galen and the Ventricular System

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ABSTRACT

This paper examines the anatomy and physiology, together with the pathophysiology, of the ventricular system of the brain, as it was understood by arguably its greatest exponent in Western Antiquity, Galen. According to him, the purpose of the ventricles was to elaborate, store and distribute *psychic pneuma*, the motive force of Galenic neurology, throughout the nervous system. However, impressive as the delineation of the ventricular system is, the details of this distribution are not forthcoming from Galen. Finally, I discuss the ventricles as the site of intellect, a notion only tentatively advanced by Galen, but cast into dogma by his successors. For all the mistakes Galen made in anatomy and physiology, the study of the ventricular system reveals a mind not dissimilar to our own.

Key words: Galen, Greek neurology, ventricular system, psychic pneuma, intellection.

INTRODUCTION

Galen (129AD–?216AD),[1] recognised the brain as the origin and controller of the nervous system. An index of his success as a neuroscientist is the long shadow his conception of the brain and the nervous system cast, a shadow the umbra of which covered the first half of the nineteenth century.[2] Several articles in this Journal have drawn admirable attention to the role of the Greeks in the history of the neurosciences (Clifford Rose, 1993; Freemon, 1994; Karenberg, 1994). The purpose of this article is to discuss Galen's use of the ventricular system. In what follows, I shall examine the ventricles of the brain in order to determine how Galen viewed them in terms of their morphology and topography, and with what properties Galen endows them. Galen uses *psychic pneuma* to account for the functions of the ventricular system. For Galen, psychic pneuma is the capstone of his physiological system. Through it, he seeks to account for all aspects of the nervous system, from the motor and sensory actions of the nerves to the process of intellection itself. The requisite for Galen's competence in the neurosciences is anatomy. It is dissection which enables Galen to advance the claims for nervous function he makes in the great anatomical and physiological works which are *On the Use of Parts* (*De usu partium, UP*), *On the Doctrines of Hippocrates*

[1] The traditional dates for Galen are 129AD–199AD, giving him a convenient threescore years and ten. However, the evidence has been carefully sifted and a convincing case made by V. Nutton for Galen's death as being about 216AD, certainly after 209 (Nutton, 1995).

[2] "The Galenic model of the nervous system continued to attract considerable support, especially in Britain, as late as the 1830's." (Clarke & Jacyna, 1987, p. 30.) That the brain was the origin of the nervous system was, needless to say, not challenged. What was successfully challenged were three key aspects of Galenic neural doctrine: (i) That the ventricles, and not the brain substance was responsible for neural function – the latter as we shall see was not held to any extent by Galen; (ii) that there is a pneuma or a fluid in nerves responsible for conduction; (iii) that the spinal cord exists only as a distributor and conductor of nerves (for this last see Clarke and Jacyna, 1987, 49–57).

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and Plato (*De placitis Hippocratis et Platonis*, *PHP*), and *Anatomical Procedures* (*De anatomicis administrationibus*, *AA*),[3] and from which I chiefly draw this paper. What is important for Galen is that he be able to illustrate pneumatic function in terms of the ventricular system. For Galen, the brain functions because it has ventricles, just as in the same way the heart operates because of its ventricles. The substance of the encephalon itself seems not to have a similar role to play, as I shall now discuss. I will next survey Galen's pneumatic physiology, and then examine the anatomy, physiology and pathology of the Galenic ventricular system, concluding with an overview of Galen's "localisation" of the intellect.

BRAIN SUBSTANCE VERSUS THE VENTRICLES

It may seem curious that the concept of localisation of psychic and physiological activity within the substance of the brain, and more importantly, that the substance of the brain was responsible for those functions was one Galen did not use to any significant extent.[4] Yet Galen based this decision on, for him, impeccable scientific grounds, namely, his observation of brain injured patients, and his vivisectional experiments.[5] For Galen, the brain as organ of control was a ventricular structure only. The transfer of such functions from the ventricles to the brain substance itself cannot properly be said to have commenced until the eighteenth century, although the first moves in this direction were made by Willis (*Cerebri Anatomie, 1664*), and Sylvius (*Disputationem Medicarum* IV,1665).[6] As far as the spinal cord and nerves were concerned, Galen regarded these as part of the brain, structurally indistinguishable from it.[7] The substance of the brain then, serves as a sort of template for nervous structure. To Galen, a nerve is partly composed of compressed brain substance – or at any rate of a substance not indistinguishable from the brain substance proper. This compression protects the nerve from injury (*PHP* 456.7–8). In *De usu partium*, Galen goes so far as to describe the substance of the brain (the encephalon)[8] as *similar* to the nerves. Yet the brain is softer; the better, it would seem, "to

[3] It is customary to cite from the traditional Corpus of C.G. Kühn, *Claudii Galeni Opera omnia*, Vols. 1–20, Lipsiae, 1821–1833. However, where better editions exist, these will be cited alone. For this paper I use the edition of Philip De Lacy (1978, 1980, 1984); Duckworth (1962) (this is a translation of the later part of *De anatomicis administrationibus*, which is only available in Arabic); *De usu partium* libri xvii, G. Helmreich, I,1907; II, 1909, Teubner. There is a very good translation based on Helmreich's edition by M.T. May (1968). All other texts cited in this paper are from the Kühn edition.

[4] For an ancient account that seems to regard the brain itself as mediating sensation, see G–J Lokhorst (1982, p. 36. This theory, "fell into complete oblivion. The reason for this is probably the popularity of later accounts of brain function in which emphasis was laid on processes taking place in the cerebral ventricles; the fact that this is a unitary system overshadowed the anatomical duality of the brain."

[5] Whether Galen dissected humans himself is a moot point. He informs us (in *AA*, IIK, 385–386), that other practitioners dissected humans, either of enemies slain in battle or of the fortuitously exposed dead after burial. He does not include himself in this category, but neither does he say that he would not if granted the opportunity.
H.S. Williams concludes a discussion of this by stating, "It is possible that he did make human dissections surreptitiously, but of this we have no proof." (Williams, 1904). We know from Galen himself that he urged his own students to visit Alexandria if possible in order to augment their anatomical training—in osteology (*AA*, IIK,220). As far as we know, the practice of human dissection and vivisection began and ended with Herophilus and Erasistratus.

[6] Progress was by no means assured even after Willis and Sylvius; for example, even Flourens (1794–1867) denied the concept of cortical localisation.

[7] *PHP* 472.34–474.3; cf. 456.7, where the nerve is described as ὁμοειδές with the brain.

[8] To Galen, the *encephalon* (ὁ ἐγκέφαλος) is equivalent to our cerebrum, although our use of the term encephalon usually refers to the entire contents of the cranial cavity; the *parencephalis* (ἡ παρεγκεφαλίς) is our cerebellum. The *spinal medulla* (νωτιαῖος μυελός) referred to by Galen is our medulla oblongata.

receive sense impressions, construct images, and apperceive ideas."[9]

Taken in isolation, this could imply that Galen holds the functions of sensation, apprehension and intelligence to be mediated by the brain substance (encephalon). However, reading further, one finds Galen describing the encephalon in this way in order to better illustrate his method of dividing nerves into hard and soft; the former arise from the posterior part of the brain (motor nerves), the latter from the anterior of the encephalon (sensory nerves).[10] So we are given an anatomical reason for this division. However, a further instance of apparent cerebral localisation occurs in Galen's discussion of olfaction. In *De usu partium*, Galen informs us that as far as the sense instrument of olfaction is concerned, "The perceived material proper to this sensation must, in fact, alter a portion of the encephalon."[11] Again, one may well be forgiven for thinking that the encephalon is being affected by the sense of olfaction; however, Galen's meaning, as the text proceeds, is that this part of the encephalon acts as a covering membrane (*meninx*) for the olfactory bulb. So the substance of the encephalon may act as a conduit or protective layer, but it does not, according to Galen directly apprehend. The question is, from which part of the brain do the nerves receive their power? The faculties of apprehension, perception and reason Galen places within the ventricular system. Before outlining this system, some mention of Galen's physiology is necessary.

PSYCHIC PNEUMA IN GALENIC PHYSIOLOGY

For Galen pneuma is both an appropriate and inevitable choice for his physiological requirements. Its very generality allows Galen ample scope to construct an elaborate set of physiological argumentation, and O. Temkin (1951) is quite right to remind us that the "existence of pneuma within the body as a requisite of animal life is a basic tenet of Galen's biological and medical doctrine."[12] The creation of psychic pneuma begins when, according to Galen inspired air enters the lungs which alters it into a pneuma-like substance (πνευματώδης). From the lungs, this new entity enters the left ventricle of the heart where it is fully elaborated into vital pneuma (πνεῦμα ζωτικόν). This elaboration is made possible by the action of vital heat (ἔμφυτον θερμόν) within the left ventricle, in concert with altered venous blood from the right ventricle.[13] The vital pneuma now has access to all parts of the body via the arterial system, affording it entry to the brain where it enters two vascular structures: first the so-called *rete mirabile* or *plexus reticularis* (δικτυοειδής πλέγμα) a network of fine arteries lying at the base of the brain, and then the *choroid plexuses* (χοριοειδής πλέματα) of veins and arteries in the ventricular system, which complete the transformation of vital to psychic pneuma (πνεῦμα ψυχικόν). The ventricles of the brain do not derive all their psychic pneuma via the retiform plexus. Galen also allows the ventricles to elaborate outside air via the nasal passages, comparing the notion of air inspired in this way to that of air brought into the body (to regulate the vital heat) via the pores of the skin. The ventricles of the brain are the final repository of a psychic pneuma which will then flow out through the nerves to the effector organs of the body.

Galen allows psychic pneuma to seep from the ventricles of the brain into the substance of the brain itself, stating that there is a great deal of pneuma in the substance of the brain, and not just in the ventricles.[14] In the absence of any

[9] *UP*, I. 461.

[10] *UP*, I.461–463. See also May, 399, n41.

[11] *UP*, I.469, tr. May, 405.

[12] "On Galen's Pneumatology", *Gesnerus*, 8, 1951, 180–189 (reprinted in idem, *The Double Face of Janus*, Johns Hopkins University Press, 1977, 154–161, 160).

[13] For an account of the lungs and heart in Galenic physiology see now A. Debru (1996).

[14] *UP*, I.488.

other source, this pneuma must have percolated from the ventricles – indeed, it has to in order to account for the presence of pneuma in the nerves.[15] Galen requires this percolation for two reasons. The first is that the nerves have their origin in either the spinal medulla[16] or in the part of the brain known as the *parencephalis* (cerebellum). Galen says the parencephalis is the source of the nerves for the whole body, and pneuma has access to this area, as, for Galen, the fourth ventricle lies between the two lobes of the parencephalis.[17] This latter structure surrounds the large middle cerebral ventricle, which receives psychic pneuma from the two anterior (lateral) ventricles, and transmits the pneuma into the posterior ventricle, and thence through the spinal canal, allowing psychic pneuma access to the spinal cord.

In the case of either point of origin, the nerves must be supplied with psychic pneuma, and they obtain it from the ventricles in this way. They also obtain it via the putative connection between the channel in the spinal cord and the posterior ventricle.

The second reason is perhaps less prosaic, although it is at least equally as important. For Galen, the psychic pneuma is the first instrument of the soul, which resides "somewhere" in the substance of the brain.[18] For Galen to state that psychic pneuma seeps or percolates through the ventricular system into the substance of the brain allows him to connect the mysterious entity of the soul with its physical correlate, the psychic pneuma.[19] It was enough for Galen to localise the soul in very general terms as residing within the brain, yet at the same time excluding the soul from the ventricular system, that is, from the place of activity of psychic pneuma. To place the soul there would be to take for Galen the irrevocable step of equating soul with pneuma, lessening the importance of pneuma for his physiology.[20] It is the anatomy and physiology of the ventricular system that for Galen is of first importance, and the pneuma that is made and which flows from this system. I shall now examine the anatomy of the ventricles.

ANATOMY OF THE GALENIC VENTRICULAR SYSTEM

The account Galen presents of the ventricular system is one which illustrates a meticulous and masterly knowledge of the subject at hand. Galen envisaged two anterior ventricles, a middle and a posterior ventricle, all in communication with each other. In contemporary terms, this

[15] R.E. Siegel asserts that, for Galen, "the concept of diffusion of pneuma throughout the brain was in full agreement with the concept of the Stoic philosophy of the mutual penetration of material agents." (Siegel, 1968). The notion that Galen utilised Stoic theory of mixture (κρᾶσις) in this way is highly improbable, as it would leave him open to the charge of following Stoic physics, and Galen is always at pains to disassociate himself from any School or grouping. In any case, Stoic mixture theory is not as straightforward as Siegel presents. Siegel however, is quite right in his next sentence, "To Galen, the *pneuma psychikon* represented the activator of the brain." ibid.

[16] In Plato's *Timaeus*, 73b1–5, the spinal marrow and the brain are continuous structures (although the 'marrow' here also means bone marrow) The notion that the nerves connect to the brain goes back to Alcmaeon of Croton (See the discussion in Taylor, 1928).

[17] *UP*, I.488. Earlier, at I.482, all nerves which supply the body below the head arise from the parencephalis *as well as* the spinal medulla.

[18] *PHP* 444.4–6. And see 598.26–600.4, where Galen *is* definite about the number of forms of the soul, their location and function. These are facts which for Galen can be scientifically demonstrated. Galen is notorious in professing uncertainty as to the exact nature of the soul. At *PHP* 598.30ff, for example, he asserts that he has "demonstrated" the soul has three forms, but as to its substance or anything else about it, he remains silent. All such theorising is outside the domain of practical medical science, it belongs to philosophers (*PHP* 600.15–19).

[19] See for example, *PHP* 444.6.

[20] At *PHP* 170.6ff, Galen states that Chrysippus, the founder of Stoicism holds that the soul is connate pneuma (ψυχὴ πνεῦμά ἐστι σύμφυτον, 170.9), and exists as a continuum throughout the body. Such an undifferentiated pneuma is hardly the vehicle with which to complement and enhance different and discrete anatomical structures.

is almost correct, but there are some differences. There are two lateral ventricles (Galen's anterior ventricles), each communicating with each other and with the third ventricle (Galen's middle ventricle) through the interventricular foramen. The third ventricle communicates with the fourth ventricle (Galen's posterior ventricle) by the cerebral aqueduct of Sylvius. This aqueduct is relatively large, and Galen says that some anatomists have referred to it as a ventricle; his position is one of indifference. The fourth ventricle (which also contains choroid plexuses the existence of which Galen here denied), then communicates with the spinal cord at the spinal medulla.[21] In this, as in his work with the nervous system in general, Galen is in debt to the pioneering work of the Alexandrian anatomists Herophilus and Erasistratus.[22] Galen records his own work on the ventricles in *Anatomical Procedures*, which is a model of the prosector's art,[23] and in *De usu partium*.[24] In Chapter 7 of the former, Galen, working backwards from the posterior ventricle, provides the following description, which is worth quoting at length:

> For if you proceed carefully, you find that the part which the anatomists have compared to the sharpened end of the writing reed is fashioned similarly to an outflow which discharges into the spinal marrow. Further you see how, above this part, a passage opens out from the posterior ventricle, which extends itself to the middle ventricle.[25] Then you see how the two anterior [*R. and L. lateral*] ventricles open themselves, discharging into the middle ventricle... And you see how the anterior end of each of the two anterior ventricles [inferior horn] goes to each one of the two nasal cavities like a hollow horn, wide at its commencement from its upper part and then steadily narrowing itself... Previously also, if you will, inspect thoroughly the discharging effluents on the two sides [R. and L.] of the anterior ventricles, and remove completely all the parts lying around them, so as to get a fair view of the duct which comes out from the end of each of the two ventricles, noticing how for a wide stretch it descends in the same way as the commencement of the spinal marrow [central canal].[26]

The fact that there are two anterior (lateral ventricles) is as a reserve in case one is injured (*UP*, I.481–482). Galen bases this on an actual case-history he had seen, where a young man having been injured in one of the anterior ventricles, survived.

If both had been affected, Galen informs us, the result would have been immediately fatal. Here Galen couples a clinical observation with

[21] It is also useful to note May (1968) here, "Galen usually calls the lateral ventricles of the cerebral hemispheres anterior ventricles; our fourth ventricle is his third and vice versa, except that... he calls our number three the third ventricle. He also frequently calls our third ventricle the common space between the two anterior ventricles." op. cit., above, 414 n.66.

[22] "Herophilus' knowledge of the anatomy of the brain is particularly striking when compared to that of his predecessors... the neuro-anatomical knowledge of the brain remained scanty until Herophilus performed his dissections."
H. Von Staden (1989, pp. 155–156). However, as Von Staden also points out, "unfortunately, as in the rest of Herophilus' anatomy, what has survived most clearly and copiously is Herophilus' innovative anatomical nomenclature rather than his anatomical descriptions or theories. Nevertheless, even the evidence concerned primarily with nomenclature provides rich indications of his remarkable advances over his predecessors." 157–158.

[23] Book IX, IIK, 717–731. The description is continued in the Arabic translation of *AA*, in chapters 6 and 7 of Duckworth's edition (1–6).

[24] I.481–487; I.489–496.

[25] This passage between Galen's posterior and middle ventricles (third and ventricles) has been the source of some controversy. It does not appear to be the cerebral aqueduct (of Sylvius), which connects our third and fourth ventricles, and which lies quite deep in the brainstem. What Galen probably did was to create a false passage (an easy thing to do in dissecting delicate structures, especially if you run parallel to the tissue plane) by tearing the *velum medullare superius*, which covers the third ventricle, and whose name signifies a delicate structure; through this opening a probe can be inserted into the fourth ventricle without undue difficulty.

[26] 2–3, Duckworth.

sure anatomical knowledge.[27] The function of the anterior ventricles is to elaborate psychic pneuma (obtaining air for the purpose via their supposed communication with the olfactory apparatus), and to act as a discharge port (via the nostrils) for the residual products of elaboration and the phlegmatous waste products of the brain.[28] This reasoning also explains the small size of the posterior ventricle – this cavity receives the perfectly elaborated psychic pneuma, and has no elaborative tasks to perform. Hence it is smaller than the others.[29]

The middle ventricle is large, larger than the anterior; the reason is that it lies under and between the cerebellum (*parencephalis*), and is in proximity to the beginning of the spinal cord (*spinal medulla*). Since, Galen informs us, nerves take their origin from either the spinal medulla or the parencephalis, it makes sense to site the largest ventricle with them, as one would expect they would both need access to a large supply of psychic pneuma.[30] Here Galen interprets the topographic anatomy of this part of the brain strictly in the light of this particular aspect of his physiological requirements.

At this point it may be asked, what governs the passage of psychic pneuma through the ventricular system? Galen describes a physical structure in the brain which regulates the passage of pneuma between the third and fourth ventricle: the vermiform epiphysis (σκωληκοειδὴς ἐπιφύσεως or *vermis superior cerebelli*).[31] This worm-like structure connects the two lobes of the cerebellum, and Galen assigns to it the function of a regulator valve to pneumatic flow into the posterior ventricle. It seems to move not unlike a worm, and its ululations serve to control the flow of psychic pneuma.[32] However, what in turn governs *its* movements is not made clear, unless it is pneuma itself, for Galen does hold that psychic pneuma moves the brain.[33] All we may perhaps conclude from this is that Galen, wishing to assign a function to this vermis, hit upon the (for him) most obvious one, but is unable to explain what lies behind the mechanism of its action – its *purported action*, it would seem, is all the explanation Galen requires. For us, however, it is once more a reminder that certain areas of his neurology are constructed on foundations not as secure as are the anatomical expositions which surrounds them.

If we now turn to review the actions of the ventricular system, Galen, in a series of ingenious experiments, established the premise that if the ventricles were disrupted, then the consequences varied from unconsciousness to death. Galen then went on to conclude from these experimental observations that pneuma was the mechanism behind these events, and that, in the case of interruption to some parts of the ventric-

[27] *UP*, I.481–482. See the discussion of Galen's account of the injuries to the ventricular system in A. Souques (1933, pp. 316–317, 338). And Wilkie rightly notes that Galen's "experiments on the nervous system, in particular, carry total conviction as accounts of what he had himself actually done and seen." (Furley & Wilkie, 1984, p. 48.)

[28] *UP*, I.481.

[29] *UP*, I.486. Incidentally, this serves as another reason why there is no choroid plexus in this ventricle.

[30] *UP*, I.482.

[31] It is described in detail at *UP*, I.491–494.

[32] A 9th century account of its function is perhaps a clearer exposition than Galen's, stripped as it is of complex anatomical descriptions, and runs as follows, "But this canal is not always open, for it contains in its hollow something resembling a worm by which it is blocked until Nature intends to admit the animal spirit from the middle to the posterior cavity. When she intends to move it on, she withdraws that worm-like (structure) and gives passage to such (quantity) as she wishes to let pass; after that she returns it to its place." From "The Second Treatise on the Nature and Uses of the Brain", from M. Meyerhof (1928, 15–19, §26–33).

[33] *PHP* 230.16–19. We get no explanation as to *how* this occurs. In *AA* ix.11, we are told that when the brain of a living animal is exposed, "you see the whole brain, so long as the animal does not cry out, rises and sinks slightly with a movement which resembles that of the pulsation... of the arteries," 16, Duckworth. On the following page, the reasons for this movement are that, "in consequence of its softness, the brain rises upwards when the animal cries out." 17, Duckworth.

ular system, the effects were reversible because the supply of pneuma could be renewed, following closure of the affected ventricle. Let us examine this in more detail.

APPLIED PHYSIOLOGY AND PATHOPHYSIOLOGY OF THE VENTRICLES

In Book VII, Chapter three of *On the Doctrines of Hippocrates and Plato,* psychic pneuma is presented to us as being in the brain. But Galen will not allow it to be called the soul (ψυχη). Instead, psychic pneuma is located within the ventricles of the brain while it is better to suppose that the soul resides within the body (σῶμα) of the brain itself (*PHP* 444.4–5). Galen is careful not to say that he has *proved* the soul lies within the brain; it is enough for Galen's purposes that the soul resides in the brain. By contrast, Galen does not feel bound by any similar reserve in the case of the *provenance* of psychic pneuma, whose existence and functions he arrives at by inference and by anatomical demonstration. Galen now recounts his vivisection experiments with an animal's brain.[34] He notes that, with the brain exposed, the animal does not begin to lose sensation or motion. It is when an incision is made in the ventricles that these functions are lost. Galen remarks that pressure on the ventricles, as sometimes happens in trepanning (ἀνατιτραίνω), has the same effect:

> After the bone of the head has been removed, the animal being still alive, and after the dura mater has been laid bare, then when you have pulled it back with hooks on each side of the middle line at which it is doubled and descends into the brain, if you merely cut it or if you remove it entirely, the animal does not lose sensation or motion; nor does it lose them if you merely cut or if you remove that portion of it which covers all the back part of the brain. And even if you cut away the brain itself in any manner, even then the animal does not lose motion and sensation until the incision reaches on of the ventricles.
> Cutting the posterior (ventricle) harms the animal most, and next after that the middle (ventricle). Each of the anterior (ventricles) causes less serious injury, and to a greater degree in older animals, to a lesser degree in the young. Pressure on the ventricles has the same effect as incision into them; and we see pressure sometimes applied, not intentionally, but with every effort made to avoid it, in men who are undergoing trepanation, when the bones of the head have been broken.[35]

From these observations, Galen canvasses two suppositions concerning the pneuma in the ventricles: if the soul is incorporeal, then pneuma is, as it were, its first home; but, if we hold the soul to be *corporeal*, then pneuma *is* the soul.[36] Galen now dismisses both of these suppositions by pointing out that until the pneuma is allowed to again collect, the animal is still alive, but without sensation or motion. If soul is *pneuma* then one would expect, when the ventricles are opened, that the pneuma (*qua* soul) would escape, and the animal, as well as losing consciousness, would perish.[37] This is not seen to happen and thus the soul is not pneuma.

Superficially, it is a telling argument, backed up by the kind of meticulous dissection and vivisection in which Galen excelled. Of course, we cannot determine the existence or otherwise of an entity called "psychic pneuma", as much as Galen tells us that this is just what has been demonstrated. As De Lacy comments, "Galen's point here is that since in the example cited the pneuma is not continuously present in the ventricles of the brain, it must not be too closely identified with the soul. The safer view is that the soul dwells in the brain and uses the pneuma as its instrument."[38] As if to stress this point,

[34] Galen experimented with many animals, even dissecting an elephant. For experiments of this nature he preferred to use goats. For dissections of the brain itself, that of an ox was preferred.

[35] *PHP* 443.14–19, tr. De Lacy [=442.22–35].

[36] *PHP* 442.36–444.1–2.

[37] *PHP* 444.8–11.

Galen has just described the levels of immobility suffered by the animal as a result of cutting into the ventricles, from the most serious if the posterior ventricle is incised, to a lesser degree of harm if the middle ventricle is damaged. Galen even divides the amount of damage sustained in injury to the anterior ventricle (which is least harmed) on a chronological basis; damage there is more apparent in the older animal, less so in the young.[39] Further, the ventricles are also defined by what parts of the nervous system they control, the posterior one for example being concerned with sensation and voluntary motion.[40] The mere fact that psychic pneuma has *differentiae* of functions vitiates the localisation of soul *within* the ventricular system, but it also makes its putative localisation in the brain problematic at best, for if Galen has gone to such pains as to demonstrate the *differentiae* of psychic pneumatic function, does one need to look beyond this to a soul? Galen's arguments are more convincing with respect to pneuma and its status as a physiological agent in the body, than they are to the essence of the soul, or even to its existence, and this is perhaps his intention. Galen's agenda is not to demonstrate the actions of the rational or hegemonic soul, but of a governing agency located within the ventricular system of the brain.

Damage to certain parts of the ventricular system were almost uniformly fatal – whether Galen found immediately fatal results on opening these parts of the ventricular system or whether the effect was apparent over time, and in spite of closure of the breech is not specifically recorded. There is thus a scale of function (based on relative and absolute incapacity as recorded by experiment) between the ventricles. There are also some differences in accounts of damage to the ventricular system.

For example, in *De usu partium* I.481, Galen notes his surprise at seeing a youth from Smyrna who had an injury to one anterior ventricle, and yet lived; were both to be affected, states Galen, death would be immediate. This account sits a little oddly with the evidence of the *PHP*, where we are told that damage to each anterior ventricle causes the least serious injury as compared with the other two. However, Galen does qualify this by saying that such a finding is age dependent, with older animals suffering more than those who are young.[41] It is an incision to the posterior ventricle that creates the most harm, with damage to the middle ventricle being the next most severe.[42]

What stands out in the account of the experiments in incising the ventricles which Galen recounts in *PHP* 442.19-35, is the stress he places on the notion that damage to the brain substance, whether involving its incision or removal, has *no effect* on motion or sensation. It is the integrity of the ventricular system that counts, with some ventricles seen as more important for life than the others in this regard. The most important, as we have noted, is the posterior ventricle. This is expressed in the following which is worth quoting at length:

> Should the brain be compressed on both the two anterior ventricles, then the degree of stupor which overcomes the animal is slight. Should it be compressed on the middle ventricle, then the stupor of the animal is heavier. And when one presses down upon that ventricle which is found in the part of the brain lying at the nape of the neck, then the animal falls into a very heavy and pronounced stupor. This is what happens also when you cut into the cerebral ventricles, except that if you cut into these ventricles, the animal does not revert to its natural condition as it does when you press upon them. Nevertheless it does sometimes do this if the incision should become united. This return to the normal condition follows more easily and more quickly,

[38] De Lacy, in his commentary to 444.4–8 (675).

[39] *PHP* 442.30–32.

[40] cf. De Lacy's commentary to 442.30, at 675. See also J. Pigeaud (1988, pp. 176–178.

[41] *PHP* 442. 30–32.

[42] *PHP* 442.30.

should the incision be made upon the two anterior ventricles. But if the incision encounters the middle ventricle, then the return to the normal comes to pass less easily and speedily. And if the incision should have been imposed upon the fourth, that is, the posterior ventricle, then the animal seldom returns to its natural condition; although nevertheless if the incision should be made into this fourth ventricle, provided that you do not make the cut very extensive, that you proceed quickly, and that in the compression of the wound in some way or other you employ a certain amount of haste, the animal will revert to its normal state, since the pressure upon the wound is then temporary only – and indeed especially in those regions where no portion of the brain overlies this ventricle, but where the meninx only is found.[43]

Galen's Alexandrian predecessor, Herophilus, "...seems to have been the first anatomist to distinguish and describe the main ventricles of the brain. He ascribed great physiological significance to the fourth ventricle in particular..., apparently because of its proximity to the spinal cord and the motor nerves."[44] The fourth ventricle (Galen's posterior ventricle) is for him, too, the most important, and for similar reasons, as we have noted above. We may also note that, in addition, Galen takes Herophilus's colleague, Erasistratus, to task for the latter's apparent assertion that it is damage to the covering membrane of the of the spinal cord (*meninx*),[45] which is responsible for an animal becoming motionless. Erasistratus made this statement after seeing oxen felled by a blow to the first vertebra, cutting the meninx; it is rather because damage to the meninx exposes the posterior ventricle,[46] for, as Galen earlier comments, the posterior ventricle empties out via a single channel into the beginning of the spinal medulla (ie. the top of the spinal cord).[47] Lastly, Galen validates his interpretation of these observations by pointing out that damage to the meninx anywhere else does not result in the animal becoming motionless.[48]

And Galen says also that, "the animal, when one pierces or incises the thin meninx, sustains no derangement as a result, just as none befalls it if the brain should be incised without the incision reaching as far as to one of its ventricles."[49]

As far as other examples of pathophysiology to the ventricles, it is worth turning to Galen's treatise, *On the Affected Parts* (*De locis affectis*), where he maps out the effects of blockage to the ventricles in terms of mental as well as physical effects on the patient, and these effects are sometimes epileptic in nature. Galen holds that it is reasonable to state that epilepsy is due to a blockage caused by deposits of a thick humour, which impede the flow of psychic pneuma through the intercommunicating channels between the ventricles, its effects (its motor and sensory manifestations) being due to irritation of the origin of the nerves in the brain by this thick humour,[50] Thus if the anterior ventricle is effected (whether by epilepsy or, more usually, by haemorrhage or infarction), the person is deprived of movement and sensation, and the condition of the patient is one of stupor (κάρος);[51] convulsions or respiratory distress

[43] *AA*, IX.12. 19, Duckworth.

[44] *Herophilus*, op.cit., above, 158. cf., 247–248, and the testimonia of T77a,b; T78, T137, and T138, together with the commentary on 389–390.

[45] The part of the meninx which lines the cerebrum is called the λεπτή μῆνιγξ; Galen tells us that the term μῆνιγξ used to be applied to all covering membranes; custom has decreed that it now be reserved for the brain, but Galen does not know who initiated such a change (*AA* IIK, 715–716; cf. *PHP* 440.20ff, where a quotation from Erasistratus has him referring to it in the context of the brain).

[46] *PHP* 446.22–27.

[47] *PHP* 446.20–22.

[48] *PHP*, 446.27–29.

[49] *AA*, IX.12, 20, Duckworth.

[50] VIIIK, 173.

[51] VIIIK,231.

may also occur. These convulsions are not necessarily epileptic in nature; indeed, Galen earlier is at some pains to discount the anterior ventricle form the point of view of a *causative* role in epilepsy,[52] With the middle ventricle affected, stupor only seems to occur.[53] From the point of view of severity of symptomatology, it is once again the posterior ventricle which in Galen's view is the most important, considering what functions it transmits via psychic pneuma.[54] That is to say, interruption to the production or movement of psychic pneuma causes effects on these above mentioned faculties. Behind these faculties lies the rational soul, residing "somewhere" in the substance of the brain, which initiates these actions; its location, as well as the brain substance itself, whether in terms of its substance or of its convolutions, is not for Galen a matter of neurological import. Since the ventricles are of such importance to Galen's neurology, it is perhaps worthwhile to briefly examine the fate of psychic pneuma once it leaves the ventricular system. Here, however, there are no ready answers.

THE QUESTION OF NERVOUS ACTION

From the posterior ventricle, pneuma supposedly moves down the spinal cord, thereby having access to all the nerves. The nerves grow from the brain, being thickest at the point of origin.[55] Galen also describes the spinal nerves that appear to grow out from the spinal cord like the branches of a tree (*PHP*, 380.34–36). At its point of origin, the spinal cord is thickest, and Galen uses this to show that in fact it does arise from the brain. Galen divides nerves into two broad types, motor and sensory.[56] Motor nerves are hard nerves, arising from the spinal cord (the hardest nerves arising from the lower end of the cord).[57] Sensory nerves, on the other hand, are soft, originating from the brain.[58] Motor nerves deal with voluntary motion only, and must be made hard to cope with often vigorous motion. Sensory nerves, dealing with sensations which are often subtle (like touch), need a softer substance in order to interpret these sensations.[59] Here the morphology of the nervous system is pretty well determining the classification of neural function, or at least Galen is able to take advantage of the morphological appearance of the nerves for his own physiological purposes. Involuntary motions, being natural ones like the motions of the arteries and the heart, do not require neural involvement (*De motu musculorum*, IVK,442).[60] On the other hand, to move is to initiate muscular activity, which is an activity of the psychic pneuma in the ventricular system of the brain and is therefore a voluntary action. Nerves are distributed for three specific ends, voluntary motion, sensation, and perception, with this last being interpreted as awareness of pain.

[52] VIIIK, 175. This does not exclude the possibility of course that if the entire ventricular system is affected, epileptic seizures will not occur.

[53] VIIIK,232.

[54] VIIIK,175

[55] *PHP*, 380.29–34; Galen is describing the facial nerve and its branches.

[56] The distinction goes back to Herophilus. Cf. Von Staden, op.cit., *Herophilus*, 250–252.

[57] Although arising from the spinal cord, they ultimately originate from the brain; cf. *De motu musculorum*, IIK,369, where Galen notes that the substance of the spinal cord is similar to the brain, but, as it is compressed, is harder.

[58] *UP*, I.459; II.42–43. Galen also recognised mixed nerves (i.e, nerves with motor and sensory functions), cf. *UP*, I.458–459.

[59] cf. *AA* XIV 188–189, Duckworth; *PHP* 94.23–27. As E. Savage Smith notes, Galen "felt that pure sensory nerves were very soft and pure motor nerves very hard, for to be able to perceive the nerve had to be alterable, while to cause motion it must be hard and strong." (Savage Smith, 1971, p. 80).

[60] *De motu musculorum* reiterates that the heart is not a muscle (IVK,377). The heart is an organ of nature by Galen's definition of involuntary motion (IVK,455).

What does Galen postulate flows through the nerve, and how does the nerve ending convey motion to the muscle? Pneuma is the obvious answer in both cases, but the precise role of pneuma is never fully articulated.[61] Consider the question of vision. The eye and brain are in direct communication with each other via the optic nerve,[62] whose source Galen held to be the anterior ventricles.[63]

The optic nerves are hollow, with a perceptible channel to conduct pneuma (*UP* I.463).[64] Galen asserts that this hollowness was first described by Herophilus,[65] although it should be pointed out that Aristotle, in *Historia animalium*, described so-called passages (πόροι) which link the eye to the brain.[66] For Galen, the optic nerves are the only ones with perceptible channels.[67] This passage is important also since it is on the strength of this observation of the perceived hollowness of the optic nerves[68] that Galen thought that other nerves had, if not a similar channel, then at least an analogous structure in order to convey either pneuma or its equivalent.[69] That is to say, pneuma could be said to "flow" in that lumen from brain to the nerves.[70] Yet Galen himself seems to have held that it was not so much pneuma as a *substance* that flowed through the nerve, but rather a series of changes set up by pneuma that coursed through the nerve tissue (here the *quality* of pneuma is important). In any case, other nerves do not seem to need much psychic pneuma to function properly (which is indirect supporting evidence for their utilising pneuma as a quality rather than as substance). However, in another text, *De motu musculorum*, questions of substance or quality of pneuma are replaced by the arguably simpler device of a power (δύναμις) flowing from the brain through the nerves and

[61] Although in *De plenitudine*, VIIK, 534, Galen does say that it is the pneuma flowing through the nerves which is responsible for muscular motion; but this is denied later in the same text (VIIK, 563). and see De Lacy's commentary to the *PHP*, 678 for 452.8–11.

[62] *AA*, 187–188, Duckworth.

[63] At the so-called θάλαμος of the ventricles, *De usu partium*, II.384. In this regard, E. Savage Smith notes that "Galen here is referring not to the thalamus of modern terminology, but to the recess (inferior cornu) in the lateral ventricles which he considered to be the source of the optic nerve.", op.cit., 85; cf. *UP*, II.384, where Galen also states that he proves this in Book 13 of his (lost) *De Demonstratione*. The ventricular connection with the optic nerve is described in detail at *PHP* 448.25–450.9.

[64] This is repeated in *De nervorum dissectione*, IIK,833; to some anatomists, however, they are channels only and not nerves (IIK,833). See also *UP*, II.384, and *PHP* 448.25–29.

[65] For example at *UP*, II.93, Galen says Herophilus called them πόροι. And see *De symptomatum causis*, VIIK,88–89, where the term αἰσθητικὸν πνεῦμα is used instead of πνεῦμα ψυχικόν; for πόρος, see the discussion and references in Von Staden, *Herophilus*, op.cit., 237–238.
Herophilus, it would seem, reserved the term "not for all sensory ducts or all sensory nerves, but specifically for the optic nerve, and with explicit—and correct—reference to its unique lumen." 237.

[66] *HA*, 494b25–495a18; *GA*, 744a10–11. In this regard note that Aristotle's anatomical knowledge "does represent an advance over that of his predecessors in several respects. Thus, in his *Historia animalium*, he gives a respectable account of the meninges (dura and pia mater), distinguishes between cerebrum and cerebellum, mentions a cavity in the brain, and discusses three controversial 'ducts' (poroi) which lead from the eye: the two larger ones [trigeminal and optic nerve?] to the cerebellum, and the smallest [oculomotor nerve?] to the cerebrum." *Herophilus*, op.cit., 157.

[67] The hollowness is noted at *UP*, II.93, and at *De sympt. caus.* VIIK,88f. In *De locis affectis*, Galen says that the anatomists indeed call the optic nerve τὸ τρῆμα because the channel is visible only in this nerve (VIIIK,219). However, in *AA* XIV.2, Galen says the duct is "difficult to expose to view", 187, Duckworth.

[68] The supposed *beginning* of this channel—where the anterior ventricle meets the optic nerve—is said however by Galen to be difficult to see (δυσθεώρητος, *PHP* 450.3).

[69] *PHP* 440.15–19; 456.5–11.

[70] "The basic supposition was that messages could travel along the lumen of the hollow nerve, and although subjected to various modifications, the theory was still alive in the early 1800s.", Clarke and Jacyna, op.cit., above, 160.

hence to the muscles. This power is not innate to the nerves; they are simply carriers of a neural δύναμις from the brain.[71] What all this means is that, however much the ventricles rank in importance for Galen, and that he goes to some lengths to affirm the existence of psychic pneuma as his effector agent in the nervous system, he remains uncertain as how best to describe its operations. When he turns to discuss the localisation of intelligence, there is a similar uncertainty.

THE LOCALISATION OF THE INTELLECT?

Galen completely rejects the view of his Alexandrian predecessor, Erasistratus,[72] gainsaying the Erasistratean thesis that the convolutions of the brain are an index of intelligence, pointing out not unreasonably that the complexity of a donkey's brain, for example, is not related to that animal's purported intelligence. Erasistratus however, is correct, according to Galen, in stating that the cerebellum (*epikranis*) is more complex structurally than the cerebrum (*encephalon*). However, Galen had to try and answer the question that if the convoluted complexity in the brain of man does not indicate intelligence, then where *does* intelligence lie? Here, Galen disappoints. He merely states that intelligence depends on the proper blending of what he calls the "substance of the intelligent body" (ουφσ ιὠανοουɜντο∀σωὠματο∀).[73] We are never enlightened as to what this body actually *is*, nor indeed of its location: it is as much a mystery as the seat of the soul. Yet it is what Galen follows this up with which is far more interesting, and this takes us to the heart of one of the ways Galen wishes us to regard his handling of psychic pneuma. For Galen now places intelligence strictly in pneumatic terms (and, by inference, the whole of the cognitive process): the precision of the intellect, Galen reckons, should be put down to the *quality* of psychic pneuma, not its quantity (*De usu partium*, I. 488–489). The importance of psychic pneuma then, lies, it would seem, in its precise distillation, whether for the purposes of perception, sensation, or intellection.[74] This distillation takes place in the ventricular system. Here again, the quality of pneuma (whatever that quality may be) is of more importance than the amount of pneuma present in the brain (and, by extension, the nerves as well). After this last statement, Galen brings this line of argument to a halt, steering us back once more to a consideration of the ventricles, thereby reinforcing their importance to his readers, and to ourselves.

CONCLUSION

For Galen, the ventricles of the brain elaborate, store and distribute psychic pneuma to the nervous system. In addition, they are somehow responsible for sensation, motion, and also intellection, although I have indicated that the detailing of this responsibility does not seem part and parcel of any Galenic orthodoxy. As R. B. Todd notes, this "division.. into the imaginative, the ratiocinative, and the commemorative, and their location in respectively the front ventricles, the middle ventricle, and the back ventricle of the brain, is a doctrine that Galen hints at rather than specifies."[75]

Galen is content to showcase his considerable talents in demonstrating the anatomy and physi-

[71] IVK, 371.

[72] Erasistratus' neurological work would appear to be more detailed than that of his senior colleague, Herophilus. See J. Longrigg (1988, pp. 480–481; 1993, p. 211.

[73] *UP*, I.488.

[74] The notion that intelligence is linked with pneuma, goes back to Diogenes of Apollonia, whose ἀήρ is both divine and intelligent, ὁ ἐντὸς ἀὴρ αἰσθάνεται μικρὸν ὢν μόριον τοῦ θεοῦ (Diels, *Vorsk* II 56.3). H. W. Miller correctly interprets this as "the internal air conceived as constituting the Ψπχή which perceives and thinks." (Miller, 1948, p. 172.

[75] "Philosophy and Medicine in John Philoponus' Commentary on Aristotle's *De Anima* ", p. 107. This formal localisation was later codified, as Todd notes, "...it soon became part of an established Galenism." 107.

ology of the ventricular system, together with the effects of interruption to that system. As to more specific questions concerning intellection and perception, he is, as we have noted in the preceding section, reticent. Although under the advent of *Galenism* the ventricles were endowed with a full set of psychological correlates, this was never expressly so stated by Galen himself. Strictly speaking, therefore, it is not correct to state that the faculties of memory, perception and cognition, reside in the ventricles; they inhabit the soul itself. This is as far as Galen goes in the direction of localisation. Galen's ventricles are important as physiological organs in that their disturbance at various points leads to quantifiable physiological disturbances. This is Galen's undeniable achievement. But in the many questions he left unanswered, as to the role of the ventricles as psychological organs, in how and in what way psychic pneuma moves and acts from the ventricles to the nerves, he left his successors with more than enough material, and more than sufficient problems to which they sought convenient solutions.

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