

Greek philosophy and the discovery of the nerves

Autor(en): **Solmsen, Friedrich**

Objekttyp: **Article**

Zeitschrift: **Museum Helveticum : schweizerische Zeitschrift für klassische Altertumswissenschaft = Revue suisse pour l'étude de l'antiquité classique = Rivista svizzera di filologia classica**

Band (Jahr): **18 (1961)**

Heft 4

PDF erstellt am: **26.04.2024**

Persistenter Link: <https://doi.org/10.5169/seals-17050>

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Greek Philosophy and the Discovery of the Nerves*

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III. Aristotle

The physicians of the "Sicilian" school whose authority Plato followed in so many important assumptions of the *Timaeus* did not give to the brain a central or controlling function. For them the *hegemonikon* (if the slightly anachronistic term is permissible) was in the heart, unless it is better to say that the *hegemonikon* actually was the heart¹. Offhand it seems to be an advantage if in theories like those here studied the sense organs have to be connected with one controlling station only. Plato's 'dualistic' concern with brain and heart was apt to complicate matters. Yet in the *Timaeus* Plato has to make concessions to *ἀνάγκη*, and in this instance the *ἀνάγκη* confronting him was the state of anatomical knowledge which kept the sense functions from direct communication with the *νοῦς*.

In Aristotle's system mind (*νοῦς*) is again the highest soul function but it also is the only one that needs no physiological basis, no physiological tools, and no physiological processes to perform its activity². Thus it is given no habitation in the body; and the brain, sheltering no part of soul, once more loses the status assigned to it by Plato (and before him by Alcmaeon and our Hippocratic) and with it all significance in the psychological scheme; all that is left to it is to play a useful part in preserving the balance between the hot and the cold matter in the body³. The heart, while by no means gaining all that the brain has lost, is definitely Aristotle's central organ. More precisely, it is the abode of the nutritive and sensitive soul⁴, i.e. of the two functions which in Aristotle's psychology have succeeded to Plato's *θυμοειδές* and *ἐπιθυμητικόν*. The ethical orientation which characterized Plato's psychology has yielded to a scheme resting on biological foundations⁵.

One of these new developments calls for closer consideration. As has been said, the senses are now a part of the soul, and their functions are psychic functions.

* See Mus. Helv. 18 (1961) 150sqq.

¹ Cf. Wellmann, op. cit. 15ff.

² See esp. *De anima* II 2, 413 b 24ff.; *De gen. an.* II 3, 736 b 27ff.

³ *De part. an.* II 7, esp. 652 b 5–653 b 8; see also *De sensu* 438 b 29ff.; *De somno* 457 b 27ff.

⁴ See *De iuv.* 3, 469 a 5ff. *ἀνάγκη καὶ τῆς αἰσθητικῆς καὶ τῆς θρεπτικῆς ψυχῆς ἐν τῇ καρδίᾳ τὴν ἀρχὴν εἶναι*. Many other passages could be adduced (e.g. *ibid.* 469 a 23ff.; b 3–13; *De part. an.* II 1, 647 a 25–32; III 5, 667 b 22ff.).

⁵ The *Timaeus* includes accounts of nutrition and sense perception but does not treat them as activities of soul. Although some relation of *αἰσθησις* to soul is admitted (e.g. 61 c 6, 69 d 4) this process is on the whole conceived as coming to pass between physical objects and the sense organs of the body. See for a comparison of Plato's and Aristotle's psychological schemes AJP 76 (1955) 148ff.

This is bound to have some effect on our problems. If perception is an act of the soul we may wonder whether the relaying of perceptions to the central organ is now entirely the soul's own business, to be transacted by communication between a peripheral station and the sensory center, and whether the body's cooperation is at all needed. As Aristotle conceives of it the sensory soul is both differentiated and unified⁶; its unifying aspect is represented—in some way—by the 'common sense' (*κοινὸν αἰσθητήριον*) which, besides performing certain other tasks, correlates the reports of the individual senses⁷. We may ask once more: what is the body's contribution? Physical and even external agents (the air) had once been paramount but now it almost looks as though Aristotle for the relaying of sense impressions did not need the body at all.

The body's share in the process has indeed been reduced. An act of perception on the part of a sense organ is for Aristotle the actualization of a potentiality inherent in this organ. For this actualization he uses the word "movement"⁸ (*κίνησις*), i.e. the same term which Plato had employed for the local motions and displacements of particles in response to stimuli. Yet in Aristotle's philosophical language "movement" has many meanings and facets and it is doubtful whether the movement or the actualization occurring when the eye sees or the ear hears has any physical or physiological aspect. Nor does the "common sense" which receives, collects, and synthesizes depend for its functioning on any physiological process. So far at any rate the incorporation of all these functions into the scheme of soul appears to entail a lessening of the interest in their physiological explanation.

It cannot be said that this result was inevitable. On the whole Aristotle thinks of soul and its parts as acting in cooperation with the bodily organs. *δεῖ γὰρ τὴν μὲν τέχνην χρῆσθαι τοῖς ὀργάνοις, τὴν δὲ ψυχὴν τῷ σώματι*⁹. In Book V of the *De generatione animalium* Aristotle shows greater readiness than in the *De anima* to specify what physical changes come to pass in the sense organs while they function¹⁰ but the doctrines in question are rather peripheral and have in any case no bearing on our topic.

With these observations and considerations in mind we may wonder what to make of the fact that the relaying of perceptions to the heart is again a "movement". In the first chapter of *De somno et vigiliis* Aristotle, reaffirming his conviction that "perception is peculiar neither to the soul nor to the body" (but a joint function of them) declares: *ἡ λεγομένη αἰσθησις ὡς ἐνέργεια κίνησις τις διὰ τοῦ σώματος τῆς ψυχῆς ἐστίν*¹¹. Here it is reassuring to learn that the "move-

⁶ See the helpful remarks of W. D. Ross, *Aristotle, Parva Naturalia* (Oxford 1955) 35.

⁷ *De an.* III 2, 426 b 17–427 a 16; *De somno* 2, 455 a 12–21.

⁸ *De an.* II 5, 416 b 33. 417 a 14ff.; 7, 419 a 13ff. 25–28; 8, 420 a 30; *De sensu* 6, 446 a 20ff.; 7, 447 a 14 al. Cf. Plat. *Tim.* 64 b 3ff. (43 c 4).

⁹ See *De sensu* 1, 436 a 6ff. the enumeration of *κοινά* (joint actions) *τῆς ψυχῆς καὶ τοῦ σώματος* which includes *αἰσθησις*; cf. *ibid.* b 6ff.; *De gen. an.* II 1, 734 a 19ff.; *De an.* I 3, 407 b 25f.

¹⁰ I, 779 b 13–781 a 13; 2.

¹¹ *De somno* 1, 454 a 9. Note *De an.* I 4, 408 b 15: there is *κίνησις* in the soul, sometimes

ment" passes "through the body". Still more encouraging are some statements in *De somniis*. In chap. 3 of this treatise we learn that movements from the sense organs "reach the principle" (*ἀφικνεῖσθαι τὴν κίνησιν πρὸς τὴν ἀρχήν*) and that the specific sense functions "report" (*εἰσαγγέλλει*)—the principle may or may not assent to their reports¹². Correspondingly, dream visions arise because during the night αἱ κινήσεις αἱ ἀπὸ τῶν αἰσθημάτων γιγνόμεναι ἐπὶ τὴν ἀρχὴν τῆς αἰσθήσεως καταφέρονται καὶ γίνονται φανεραί¹³. These movements seem to be of a physical type; in fact Aristotle (in the sentence just quoted) traces them to ἡ τοῦ θερμοῦ παλίσροια, scil. into the interior of the body¹⁴. The "vital heat"—for this is the θερμόν—furnishes us with a physical substratum for the process, and if we wish to find something even more definite we shall be satisfied with what a slightly later sentence offers: ὅταν γὰρ καθεύδῃ, κατιόντος τοῦ πλείστον αἵματος ἐπὶ τὴν ἀρχήν (scil. in the heart), συγκατέρχονται αἱ ἐνοῦσαι κινήσεις, αἱ μὲν δυνάμει, αἱ δὲ ἐνεργείᾳ¹⁵.

Having suspected that the blood plays a crucial part in this process we have every reason to be pleased at finding this role here attested. Another sentence in the same section furnishes additional information: ἐνεσι δυνάμει (scil. αἱ κινήσεις) ... καὶ λύμεναι ἐν ὀλίγῳ τῷ αἵματι τῷ ἐν τοῖς αἰσθητηρίοις κινεῖνται ἔχοντα ὁμοιότητα ὥσπερ τὰ ἐν τοῖς νέφεσιν ἃ παρεικάζουσιν ἄνθρωποι κενταύροις ταχέως μεταβάλλοντα¹⁶.

These references to the blood would seem to furnish us with what we have been seeking yet we must use them with caution. They provide, it is true, a definite physiological implementation of the psychological—or epistemological—theory that the experiences of the individual sense organs reach the central organ in the heart; in fact Aristotle uses the word *διαδιδόναι*¹⁷ which we have learned to regard as a shibboleth. What gives us pause is that Aristotle so rarely refers to this function of the blood¹⁸. In his theory of the sensory soul the idea certainly does not bulk large. When everything is taken into consideration Aristotle seems to be but slightly more outspoken than Plato who, as we remember, never comes forward with a flat and unambiguous commitment to the notion that the blood acts as a messenger.

μέχρι ἐκείνης (scil. coming from the sense organs), sometimes ἀπ' ἐκείνης ἐπὶ τὰς ἐν τοῖς αἰσθητηρίοις κινήσεις ἢ μονάς. See also *De somniis* 3, 460 b 28–461 b 5 where the farther we read the stronger becomes the impression that the movement is of a physical nature; *De iuv.* 3, 469 a 10–15; *De an. mot.* 11, 703 b 27. Cf. (also for what follows in the text) Beare, op. cit. 295.

¹² *De somniis* 3, 461 a 25ff. 30ff. b 3ff.

¹³ Ibid. 3, 460 b 28–461 a 8.

¹⁴ Ibid. 461 a 5f.

¹⁵ Ibid. 461 b 11.

¹⁶ Ibid. 17ff. At b 13 it is said that in the backflow of the blood now one κίνησις and now another "will come to the surface" (ἐπιπολάσει).

¹⁷ *De somniis* 2, 459 b 1–5. In this context the larger problems elsewhere for Aristotle associated with the διάδοσις of movement (see *De an.* III 12, 434 b 29ff.; *Phys.* VIII 10, 266 b 27–267 a 20) are not particularly acute.

¹⁸ See for another rather incidental reference to it *De part. an.* II 10, 656 b 3ff.: ἐτι δὲ

In Plato the reasons for his reserve are never plainly stated; the best that we could do was to offer a hypothesis. Aristotle's reasons need not elude us. His biological treatises include much fuller accounts of the blood and all its qualities or capacities. The difficulty lies rather in making the right choice between several possibilities. For Aristotle, as for Plato and for some schools of medical thought, the main function of the blood is to supply the body with nourishment¹⁹. This makes it in Aristotle's scheme an agent of the nutritive soul. Yet nothing would prevent it from serving the sensory soul at the same time. Every reader of Aristotle's zoological works knows how often nature with remarkable ingenuity employs one and the same entity for several purposes and how much Aristotle rejoices at finding instances of the kind²⁰. Thus the connection of the blood with nutrition cannot be the reason why Aristotle hesitates to accept it as carrier of the sense perceptions. The true reason may be gathered from two passages in the second book of *De partibus animalium*. These passages say the same thing in almost the same words (so that one of them has been suspected of not being authentic). It will suffice to quote one of them: "No bloodless part is capable of sensation (*αἰσθητικόν*) nor indeed the blood itself. It is the parts made out of blood that have this faculty"²¹. The bearing of this statement on our problem is obvious; here evidently is the reason why the blood had to be ruled out and if we now wonder why the blood is not *αἰσθητικόν* we may note the relatively simple explanation given elsewhere in the same work: Since the blood provides nourishment for living beings "it yields no sensation when touched (*θιγγανόμενον αἰσθήσει οὐ ποιεῖ*). The same is the case with other residues and with the food as such whereas the flesh when touched is sensitive"²².

None of the passages here quoted has a polemical character and if we knew nothing about earlier physiological thought we might read them as mere statements of observations or conclusions pertinent to Aristotle's comprehensive theory of the tissues. But as we have not come to Aristotle in such ignorance about earlier developments we have a right to find more meaning in these peremptory sentences. They signal the end of all hope that the blood may be the looked-for carrier of the sensations. Very probably they killed some quite elaborate

τὰς ἀκριβεστέρας τῶν αἰσθήσεων διὰ τῶν καθαρώτερον ἔχοντων τὸ αἷμα μορίων ἀναγκαῖον ἀκριβεστέρας γίνεσθαι (the second ἀκριβεστέρας should be deleted.) Cf. below p. 173.

¹⁹ See e.g. *De part. an.* II 3, 655 a 33ff.; III 3f. and in particular 5. For the blood vessel system as such see *Hist. an.* III 2, 511 b 10–4. 515 a 26.

²⁰ See esp. *De part. an.* IV 9, 688 a 22–25 where nature is said to adopt this method often; for other passages see Bonitz's Index s.v. φύσις 836 b 54ff. 59ff.

²¹ II 10, 656 b 19ff.; cf. III 4, 666 a 17ff. It must be admitted that the relation of the passage in II 10 to the context is not immediately evident. The passage may well be a "note" or an "addition". I understand but do not share the suspicions of some editors and translators. We may do well to remember that for Aristotle the brain is *ἄναιμον* (*Hist. an.* III 4, 514 a 18; no blood vessels reach it). In *De part. an.* II 10 Aristotle polemizes against Plato's attempt to give the brain an important place in the system of sense functions. The principle that nothing *ἄναιμον* is sensitive furnishes an argument against this view. I grant that Aristotle could have made the connection clearer.

²² Ibid. II 3, 650 b 3ff. (cf. *Hist. an.* III 19, 520 b 14ff.).

theories. And yet we have seen that Aristotle himself occasionally falls back on the theories to which he is in principle so opposed²³.

We should realize in what a difficult situation Aristotle found himself when it had become clear that the blood cannot transmit sensations. It helps him little that he knows blood vessels "exceedingly fine and minute" whose courses end in the organs of sense and that in another context he can tell us of passages connecting the organs of smell and hearing with the small blood vessels around the brain²⁴. To be sure the latter blood vessels provide a connection with the heart, but if knowledge of this kind formerly made it possible to follow the perceptions on their way to the heart it can now no longer be used for this purpose. From the eyes too there are passages leading to the brain; these are probably the *πόροι* which had been known to Alcmaeon and which were half a century later to be identified as the optic nerves²⁵. Aristotle realizes that in the embryo the eyes separate themselves by means of these passages from the substance of the brain but any thought of bringing the brain into the scheme of sense perceptions is anathema for him; it is bad enough that some previous thinkers (including Plato) have gone so sadly astray in this matter²⁶.

We could continue to speak of hypotheses which had once seemed attractive but could not be fitted into Aristotle's scheme. The theory of particles passing on their impressions to one another²⁷ is never mentioned by Aristotle and as he is out of sympathy with the idea of atoms or particles and does not compose tissues out of particles his silence need not astonish us. We have found him inclined to attribute sensitivity to *ἐναίμα μόρια* and may add that in his scheme the flesh is sensitive and, being the organ of touch, particularly responsive to tactile impressions²⁸. But Aristotle never uses the flesh or *ἐναίμα μόρια* in general to account for the conveying of sense impressions to the heart, and although he declares that "the senses of touch and taste are clearly (*φανερῶς*) connected with the heart" and twice in his zoological works refers to *De sensu* as bearing out this declaration no physiological implementation of the statement is to be found in that treatise²⁹.

²³ Besides the passages discussed above there are others which show Aristotle under the influence of these theories. In *De part. an.* II 2, 648 a 2ff. and 4, 650 b 19ff. he sets up correlations between the composition of the blood and the degree of sensitivity. To thin and clear blood, we learn 650 b 22, corresponds an *ἐκκινητοτέρα αἴσθησις*; and even *διάνοια*, which ought to have no physical basis in Aristotle, depends according to these passages on the quality of the blood. Such correlations were germane to the system of Empedocles for whom thought is the *αἷμα περιχώδιον* (B 105). Aristotle's debt to the "Sicilian" tradition is here patent (note also *Vorsokr.* 31 A 86, 10f.). I have discussed these remarkable doctrines more fully in *Philos. Rev.* 59 (1950) 464ff.

²⁴ See *Hist. an.* III 3, 514 a 20ff.; *De gen. an.* II 6, 744 a 2ff.; cf. also *De part. an.* II 10, 656 b 17ff. and (for the ear) *Hist. an.* I 11, 492 a 19ff.

²⁵ *De gen. an.* II 6, 743 b 36ff. 744 a 5-14; *Hist. an.* I 16, 495 a 11-18. On Alcmaeon cf. above p. 152.

²⁶ See esp. *De part. an.* II 10, 656 a 14ff.

²⁷ See above p. 161 for the Platonic version of this idea.

²⁸ See above p. 172; for the flesh see in particular *De an.* II 11 (other passages are to be found in Bonitz's Index 673 b 15ff.).

²⁹ See *De sensu* 2, 439 a 1-5 (cf. 438 b 2-439 a 1); *De part. an.* II 10, 656 a 29f. and *De gen. an.* V 2, 781 a 21ff. The last passage however bristles with problems (presently to

All that we have so far reported about Aristotle relates to the problem of sense perceptions. When Aristotle turned to the subject of bodily movements he had no such difficulties to contend with. Here the field was not littered with débris of unworkable theories, and propositions of Aristotle's own physics, psychology, and even ethics could be brought together to yield new and satisfactory conclusions. We shall soon present a summary of these decisions and shall see that in the *De animalium* motion the doctrine of the innate *πνεῦμα* is brought in to complete the solution of the problem. In the subject of the sense perceptions and their communication to the heart the same doctrine seems also to have presented itself as a solution—perhaps indeed as the only acceptable solution, since so many other roads of explanation were blocked. What is certain is that while in rejecting the blood as carrier Aristotle cut a link with the past, his experimenting with the *πνεῦμα* doctrine opened a way into the future. Leading thinkers of the next generation were to complete this doctrine; in Aristotle's own treatises its application is still rather tentative and sporadic.

In regard to its substance or *φύσις* the *πνεῦμα* is in most of the instances where Aristotle resorts to it hardly different from air³⁰, yet we must not think of this *πνεῦμα* as merely a new name for the air that figures in the schemes of Diogenes and the Hippocratic. The air which enters the body in the process of respiration cannot be innate³¹ whereas if we wish to understand Aristotle's conception of the *πνεῦμα* we must by all means hold on to this distinctive characteristic. The fact that Aristotle's *πνεῦμα* is innate (*σύνφυτον*) may even help us to trace its true antecedents. Air is one of Empedocles' four elements; he and his followers thought of animal and human bodies as consisting of these four elements. This being the scheme which Plato (in the *Timaeus*) and Aristotle have accepted it seems reasonable to regard Aristotle's innate air—to begin with—as a legacy of the "Sicilian" tradition³².

be discussed) and may not be genuine. That the references to *De sensu* are 'incorrect' has been noticed by others (e.g. by A. L. Peck in his edition of *De gen. an.*, Loeb Libr. [1943] 563).

³⁰ *De gen. an.* II 3, 736 b 30ff., where Aristotle takes a different view, is unique; cf. my analysis of this section JHS 1957, 119ff.

³¹ It is not necessary to set forth all differences between the two conceptions but it may be worth mentioning that Aristotle does not think of the innate *πνεῦμα* as entering, or moving through, the blood vessels. Philistion's concern with *ἐμπνοία* (frg. 4 Wellmann) may presuppose the existence of an innate *πνεῦμα*; but there is no evidence that it did or that his interests in the *πνεῦμα* were comparable to Aristotle's. Our study does not attempt to cover every aspect of Aristotle's *πνεῦμα* doctrine.

³² This view was advanced in 1913 by Jaeger (see his paper *Das Pneuma im Lykeion*, *Hermes* 48, 29ff., esp. 52ff.) who at that time still proceeded on the assumption that Diocles was a pupil of Philistion of Locroi and a member of the "Sicilian school". Jaeger's later studies on Diocles (see below p. 178 n. 1) have given this physician an entirely different place in the history of Greek medicine. As result, the connections between Aristotle's *πνεῦμα* doctrine and the Empedoclean tradition appear now in a somewhat different light. It seems to me essential that Aristotle owes to the "Sicilians" the knowledge of air as one of the constitutive elements of the body; how much more he owes to them is difficult to determine. His writings give the impression that new functions of the *πνεῦμα* are coming to light and that the doctrine is "developing". In *Scripta Minora* (Rome, 1960) 2, 264 Jaeger speaks pertinently of a "renaissance" of the *πνεῦμα* doctrine in the Peripatus and suggests that Diocles contributed a good deal to this renaissance.

The temptation of finding the *πνεῦμα* hidden behind a goodly number of Aristotelian passages is strong³³ but it seems wiser to resist the lure of this game and to confine our inquiry to the instances where the *πνεῦμα* frankly and without disguise presents itself in the text. Regarding sense perceptions there are no more than two instances. Unfortunately one of the two passages is so corrupt that it is difficult to make out its meaning and such meaning as can be extracted raises grave doubts about the authenticity of the statements.

The intact and to all appearance genuine passage may be quoted first³⁴: "Smell and hearing are passages (*πόροι*) connecting with the outer air; these passages are full of connate *πνεῦμα* (*πλήρεις συμφύτων πνεύματος*) and terminate at the small blood vessels around the brain which extend thither from the heart." The sentence is not very explicit about the role of the *πνεῦμα* in the processes of smelling and hearing, nor does it actually make *πνεῦμα* the agent of communication with the heart. Yet it does not take much imagination to see such possibilities in the offing.

What can be gathered from the obscure and barely intelligible assertions of the other passage³⁵ in the *De generatione animalium* is that *σύμφυτον πνεῦμα* is present in the central organ and that there is cooperation between the organ of hearing and the center; for there are passages (*πόροι*) between the sense organs and the center—i.e., the heart or the analogon, and the organ of hearing itself consists of air (*ἀήρ*)³⁶. The last point, scil. that the organ of hearing consists of air, is good Aristotelian doctrine³⁷ and may furnish an argument—though hardly a strong one—for the authenticity of the passage. The author also speaks of a "movement" (*κίνησις*) which enters by the organ of hearing and comes back as essentially the same by the organ of speech³⁸, the implication being that it has passed through the "pneumatic principle". Since the sentences, in addition to their other difficulties, do not tightly fit into the context, Peck is almost certainly

³³ Peck's reconstruction of Aristotle's *πνεῦμα* doctrine (op. cit., note 29, Appendix B, pp. 576ff.) is in a large measure hypothetical and much of it leaves me unconvinced. For other studies see the references given in JHS 1957.

³⁴ *De gen. an.* II 6, 744 a 2ff. (some use has been made of Peck's translation).

³⁵ Ibid. V 2, 781 a 21–b 2. For the reference to *De sensu* (a 22) see above p. 173.

³⁶ a 23–26. One may wonder whether "the point where the connate *πνεῦμα* causes in some (living beings) respiration" is that defined in *De iuv.* 15, 474 a 31ff. and one may for the subject of pulsation consult ibid. 26 but unfortunately there is nothing tangible to be gained for the understanding of our desperately obscure and difficult passage. Peck deserves our gratitude for giving us the text of Michael Scot's version. My impression is that it presents clearer thoughts, e.g. that the *πνεῦμα* causes pulsation in the veins (or arteries?)—but are they Aristotle's thoughts? And how are we to explain such a discrepancy between the Greek text and the Latin versio? The Latin which is on the whole more intelligible than the Greek may be rendered still more intelligible by adding two words whose loss would be due to a homoeoteleuton (although I do not know in which language the loss occurred): *spiritus naturalis facit in venis motum pulsatilem et facit in instrumento hanelitus <virtutem hanelitus> et similiter facit in aure virtutem auditus*.

³⁷ Cf. *De sensu* 2, 438 b 20; *De part. an.* II 10, 656 b 16f.; *De an.* III 1, 425 a 4f.

³⁸ 781 b 26–30; see also 30–33. The sense of hearing has its principle in the heart (cf. Peck ad loc. note c); this is the *πνευματικὸν μόριον* of a 32. What the moving *ὄργανον* of a 33f. is remains uncertain. Beare's hypothesis (op. cit. 334) that the *πνεῦμα* operates in the blood has no intrinsic probability; nor does it find support in the texts.

right in saying that the passage "began as a marginal annotation"³⁹. Its authenticity remains doubtful. Nevertheless this text, obscure and of uncertain authorship as it is, is valuable since it gives us glimpses of new developments in the *πνεῦμα* doctrine and in particular of the direction which this development takes. The co-operation by means of the *πνεῦμα* between an individual sense organ and the heart is an idea that we shall meet again in later philosophical as well as medical theory. Evidently in the case of the ear, an organ itself consisting of air, it was relatively easy to assume such cooperation and connection. Whether Aristotle contemplated an extension of the doctrine to the other sense organs is a question better left unanswered; his treatises include no hint of such a generalized doctrine, and as we have seen, his authorship is not even certain for the passage asserting the operation of *πνεῦμα* between ear and heart. As compared with the place secured for the *πνεῦμα* in the theories of movement and of reproduction⁴⁰, the "pneumatic" doctrine of sense perceptions is clearly still in its embryonic stage.

We have already said that regarding the subject of bodily movements Aristotle found himself in a considerably more favorable situation. His *De animalium motione* makes ample provision for the cooperation of body and soul; more specifically it shows how experiences of the soul, such as desire, imagination, and thought issue in actions of the body⁴¹. These psychic experiences produce a change in the temperature of the heart; when we think of something pleasant or frightening—something desirable or undesirable—we are subject to a *πάθος* which causes us to "warm up" or to "cool down"⁴². This change of the *θερμόν* in us makes our organs of movement, in particular the sinews and bones⁴³, dilate or contract and "it is clear that a small change taking place in a principle causes great and numerous alterations at a distance, just as when the rudder of a boat is moved ever so

³⁹ Op. cit. 564. Susemihl, Rh. Mus. 40 (1885) 583ff. arrived at essentially the same conclusion.

⁴⁰ For movement cf. the next paragraphs. For reproduction see II 3, esp. 736 b 30–737 a 8; III 11, 762 a 19–28. b 12–18; cf. also II 6, 741 b 37ff. with Jaeger's discussion, loc. cit. 46ff.

⁴¹ See esp. chap.s 6–10; for the initiation of the movement by activities of the soul see chap. 6. Cf. Siwek's analysis (op. cit. 139ff.).

⁴² See chap. 7, esp. 701 b 13–32.

⁴³ Ibid. 701 b 13ff. (the comparison with mechanisms b 1ff. is very characteristic). Obviously at 8, 702 a 17 the *ὁργανικά μέρη* which by the *πάθη* are put in the right condition are again the sinews and bones. In the *De part. an.* (III 4, 666 b 14) we read *ἔχει δὲ καὶ νεύρων πλῆθος ἢ καρδία ... ἀπὸ ταύτης γὰρ αἱ κινήσεις, περαινόνται δὲ διὰ τὸ ἔλκειν καὶ ἀνιέναι*. This corresponds to the doctrine set forth in *De an. mot.* It was because Aristotle in the passage just quoted had spoken of *νεῦρα* in the heart that his name and authority were later drawn into the controversy between those who knew that the nerves originate in the brain and those who would rather have them start in the heart (see Gal. *De plac. Hipp.* I 163 Mü., 206 Kühn)—an undeserved fate since in Aristotle's technical vocabulary *νεῦρα* denotes sinews, ligaments, muscles, but not nerves. Cf. D'Arcy W. Thompson's note (in the Oxford Translation of Aristotle, vol. 4) on *Hist. an.* III 6, 515 b 21. It is no part of this paper to collect the instances in which Aristotle incidentally and without recognizing their specific nature and function deals with entities now-a-days known to be nerves (see Ind. Arist. s.v. *πόρος* 623 a 6ff. passim). His descriptions of such entities are not the discovery whose antecedents we are tracing.

slightly the resulting change in the position of the bows is considerable"⁴⁴. We may here pass over Aristotle's observations about the nature and operation of the joints⁴⁵. What gives the scheme its peculiar significance is that here for the first time the translation of psychic processes into bodily action has been explained and traced through its successive stages.

A reader of Aristotle's treatise may be forgiven if at the end of chapter 9 he is under the impression that Aristotle has given a complete account of the psycho-physical mechanism, even though no word has yet been said about the *πνεῦμα*. This important factor is—rather suddenly—introduced at the beginning of chapter 10.

"According to the theory which defines the cause of motion desire (*ὁρεξις*) holds the middle position, moving because it is itself moved; but in animate bodies there must be a physical substance (*σῶμα*) which has a corresponding place (or function)"⁴⁶. "All animals clearly have innate *πνεῦμα* and exert their strength by means of it"⁴⁷. For questions relating to the origin and to the preservation of this innate *πνεῦμα* Aristotle refers us to discussions in other treatises, and as these discussions are not to be found⁴⁸ we may once more feel confirmed in our impression that the theory of the *πνεῦμα* is still in the process of evolving. Comparing the *πνεῦμα* with some of his elements Aristotle says that it is heavy in relation to fiery substances but light with reference to the "contrary" elements⁴⁹. Since the latter must be earth and water the position of the *πνεῦμα* in the scheme of the elements is identical with that which Aristotle usually assigns to the air⁵⁰. Evidently Aristotle conceives of the *πνεῦμα* as being air or like air and this is the reason why the *πνεῦμα*, as we here read, is able to contract and to expand, capacities essential for its specific physical tasks of initiating movement by pulling and pushing⁵¹. Another important point which Aristotle makes in this chapter is that the *πνεῦμα* must have its place in the heart; this assumption is necessary, he declares, because the principle or center of control, the *ἀρχή*, is in the heart⁵². It did not occur

⁴⁴ 7, 701 b 25ff.

⁴⁵ 8, 702 a 21–b 12. It may however be noted that these observations constitute a link between our treatise and the *De anima* which touches on the subject of the joints in III 10 (433 b 19ff.), making clear that this is the *σωματικόν*, the purely physical phase of the psycho-physical theory of movement.

⁴⁶ 10, 703 a 4ff.

⁴⁷ Ibid 9ff.

⁴⁸ Ibid. 11f. 15f. Cf. Jaeger, loc. cit. 50. A. S. L. Farquharson in the notes to his translation of *De an. mot.* (Oxford 1912, ad loc.) calls the reference "quite undetermined" but gives us nevertheless a choice between no less than five passages in other Aristotelian treatises. I cannot see that any of them offers what the references lead us expect.

⁴⁹ 703 a 23ff.

⁵⁰ See e.g. *De caelo* IV 4.

⁵¹ 707 a 19–25. The explanation advanced in this passage is not easy to harmonize with that given in 7, 701 b 13 where not the *πνεῦμα* but the organs are said to expand and contract.

⁵² 703 1 13f. (actually in the "heart or the analogon". I have also on other occasions disregarded references to the analogon since Aristotle's contributions to comparative zoology are outside the scope of this study).

to Aristotle to specify channels in which the *πνεῦμα* might flow to the limbs (or to the sense organs); yet this question was soon to present itself again, was to dominate the discussion of the medical researchers, and was to find its way also into the philosophical speculations, even if some schools continued to ignore it.

It is essential—also with a view to the next stages in the history of our subject—to note that the movements thus explained by Aristotle are “voluntary” movements⁵³. They are caused on the part of soul by *νοῦς* and *ὄρεξις*, terms which for the purposes of this treatise comprehend, or represent, other psychic functions such as *φαντασία*, *αἰσθησις*, *βούλησις*, *ἐπιθυμία*⁵⁴. The two “generic” terms in turn find their common denominator in a concept very familiar to us from the *Ethics*, *προαίρεσις*⁵⁵. Intelligence is not (as it had been in the Hippocratic author) something that comes from outside, settles in the brain, and imparts itself to our limbs, giving them also the capacity of movement. Our faculties, being *κριτικά*⁵⁶, exercise judgment; *προαίρεσις* indicates that we make a choice. The origin of actions is to be found in the psychic processes; and even the air (*πνεῦμα*) which is essential for the realization of movement is a part of our own constitution, inasmuch as all living beings are “compacted” of the four elements.

IV. Postaristotelian Doctrines

In the next generations the *πνεῦμα* acquired complete control over the functions which Aristotle had begun to associate with it. Philosophical and medical authorities vied with one another in availing themselves of its semimiraculous potentialities. The initiative for expanding its power lay probably with the medical thinkers and thus it will be well to consider them first. Unfortunately some leading men of the period—Metrodorus, the younger Chrysippus, Aristogenes—are barely more than names for us, but we may congratulate ourselves that Diocles’ dominating position and influence have been thoroughly clarified and that for Praxagoras we have lately been provided with a collection and discussion of the testimonies¹. The names of these two men are often coupled in the tradition so that it is not always possible to distinguish their respective contributions. Both thought of the psychic *πνεῦμα* as issuing forth from the heart and spreading out through some

⁵³ With involuntary movements Aristotle deals briefly in the last chapter (11) of the treatise.

⁵⁴ See chap. 6, esp. 700 b 17–24.

⁵⁵ Ibid. 23f. Cf. *Eth. Nic.* III 4 (note also ibid. 2, 1110 a 15).

⁵⁶ 6, 700 b 21.

¹ Wellmann’s collection of the testimonies for Diocles, *Die Fragmente der sikel. Schule* (Berlin 1901), is still useful, although the material has as a result of Jaeger’s researches considerably increased. See Jaeger, *Diokles von Karystos* (Berlin 1938) and also, especially for the chronology, Abh. Berl. Ak. 1938, 3 = *Scripta Minora* (Rome 1960) 185ff. (to which I refer). Jaeger has shown Diocles’ close connections with Aristotle’s work and with the Peripatus and has placed him in the generation following Aristotle; see for the chronology in particular *Scripta Minora* 199ff. and the ‘Anhang’ 230ff. The material available for Praxagoras has been brought together by Fritz Steckerl, *The Fragments of Praxagoras of Cos and of his School* (= *Philos. antiqua* 8, Leiden 1958). For Praxagoras’ *floruit* (ca. 300) see K. Bardong, RE s.v. 1735.

of the blood vessels². The younger of them, Praxagoras, is generally credited with the distinction between arteries and veins and with the belief that *πνεῦμα* moves through the former and blood through the latter³; yet Diocles must have approximated these doctrines. For we find both men cited for the explanation of paralysis as a gathering of thick and cold phlegm in the arteries and learn on this occasion that both regarded the arteries as the channels "through which voluntary motion is imparted to the body"⁴. Thus the *πνεῦμα* is the cause or agent of such motion. The ideas put forward in the *De animalium motione* have been followed up and the advance beyond Aristotle lies in the assignment to the *πνεῦμα* of specific paths of operation. These impressions are confirmed by the new explanation of epilepsy. Again Diocles and Praxagoras are found agreeing; both localize the disturbance in the "aorta" or thick artery; both speak of an accumulation of phlegmatic matter as the cause of the attacks; in this instance it is expressly stated that the *δίοδος τοῦ ἀπὸ τῆς καρδίας ψυχικοῦ πνεύματος* is blocked⁵.

For Diocles as well as for Praxagoras the heart was the central organ. Still there are indications that Diocles assumed the presence of psychic *πνεῦμα* in the brain as well. For he explained lethargy as due to a cooling of the soul *πνεῦμα* in both of these organs and in dealing with another condition—*κεφαλαία*—said that it originates in the blood vessels of the head but may spread from there to the heart⁶. It seems safe to infer that these blood vessels were for him channels of communication between brain and heart.

Praxagoras' large debt to Diocles is obvious to anyone comparing their doctrines and we have already found reasons for extending this indebtedness to what is perhaps his most notable achievement, to wit the functional distinction between veins and arteries. Still, whatever the degree of his dependance or of his originality⁷, in the development of physiology his doctrine of the arteries is a landmark.

² Diocl. frg. 59 W.; Prax. frgg. 70 and 74 (= *Anecd. med.* 3. 4). Unlike Aristotle, Diocles and Praxagoras appear to assume a continuity (and in a sense even identity) between the air entering the body through respiration and the *πνεῦμα* which under these circumstances need no longer be *ἐμφυτον*. The stages by which it again becomes *ἐπικτητον* are not entirely clear. This development, while in itself important, has little relevance to our subject and must—like some other phases of the *πνεῦμα* doctrine—here be left undiscussed. I share Jaeger's skepticism (*Diokles* 190ff.) regarding the attempts made by Wellmann and others to identify as Diocles the unnamed authority in the latter sections of the Anon. Vindicianus; the doctrines summarized in these sections can no longer be used for the reconstruction of Diocles' physiological system.

³ Prax. 9 and 85 St. According to the latter passage not Praxagoras but his father Nicarchus was the first to make these important differentiations. They are in any case not quite new (cf. Friedrich, *Hippokrat. Untersuchungen*, Berlin 1899, esp. 78); probably what enabled Praxagoras to advance beyond his (Coan and possibly other) forerunners was a fuller and more precise knowledge concerning the distribution through the body of both arteries and veins.

⁴ Diocl. 57; Prax. 75 = *Anecd. med.* 20 (for the meaning of *ἀποφύσεις* in this testimony cf. Arist. *De part. an.* III 5, 667 b 15).

⁵ Diocl. 51. Note also the aetiology of apoplexy *ibid.* 55.

⁶ Diocl. 44 and 59.

⁷ A significant new doctrine of Praxagoras may here be mentioned because it illustrates the increasing importance of the *πνεῦμα*. In his physiology respiration no longer has the

For one thing it provided specific channels for the flow of the *πνεῦμα*. For another, it included ideas pointing ahead to the discovery and theory of the nerves. According to Praxagoras some arteries become progressively thinner and finally so thin that their "walls" fall together and their lumen (*κοιλότης*) disappears. For this final part of the arteries he used the word *νεῦρον*⁸. All he may have meant is that in this final phase the appearance of such arteries resembles that of the sinews (for which the word *νεῦρον* had long been in use). However Galen⁹ gives us to understand that by the operation of these *νεῦρα* Praxagoras accounted for the movement of the fingers and of other parts of the hands. Such functions we associate with the nerves, and so, as far as we can tell, did Praxagoras' immediate successors, the great anatomists of the next generation, one of whom—Herophilus—was his pupil. Both Herophilus and Erasistratus knew motor nerves and called them *νεῦρα*¹⁰. Praxagoras, it would seem, was the discoverer of the nerves in a rather Pickwickian sense (the Greeks might have said *ἔδοκει*). He did not in actual fact find or identify a nerve but he evidently wondered to what kind of organ the extremities of the body owe their movement, identified this organ to his satisfaction, described it, and discussed its connection with the center of vitality and energy. We should like to know what becomes of the *πνεῦμα* at the point where the walls of the arteries fall together; it is difficult to imagine how it could continue to flow yet it can hardly cease to be operative.

Praxagoras may serve us as a bridge to the philosophers; for as we shall see, the Stoics in particular had reasons for appreciating his views about *πνεῦμα* and nerves and for preferring them to other and later theories¹¹. There can be little doubt that the Stoics owe their concepts of vital heat and vital *πνεῦμα* to the contemporary medical schools but an adequate assessment of their debt would require a special study¹². Suffice it then to say that physiologically speaking, the Stoics conceive of sense perception as a *πνεῦμα* which has its point of origin in the heart and which extends to, and operates in, the sense organs¹³. In the accounts of their system we read of *πνεῦμα* currents issuing from the *hegemonikon* and reaching eyes, ears, and other organs of perception. Most of these accounts summarize the doctrines of Chrysippus whom we find speaking of these currents as spreading out through the whole body, filling all limbs with vital spirit, causing the body to grow, producing movement, and making the senses operate¹⁴. Yet

function of cooling the vital heat (which had been Aristotle's and Diocles' view) but provides nourishment for the psychic *πνεῦμα* (frg. 32; cf. Diocl. 15).

⁸ See the relatively full account in Galen *De Hipp. et Plat.* I 1 (143, 6 I. Müller).

⁹ See the preceding Note.

¹⁰ See below pp. 184ff.

¹¹ See below p. 195.

¹² Cf. G. Verbeke, *L'évolution de la doctrine du pneuma* (Paris and Louvain 1945) 12ff.

¹³ See *St. V.F.* II 71 and also e.g. II 850. For Zeno in particular we find attested the soul as *πνεῦμα* (I 128. 135f. 140 al.), its *κρᾶσις* throughout the body (I, 145), the *διάδοσις* and *κίνησις* from the surface of the body to the *ἀρχή* (I, 151), soul as mover (I, 135. 136 ?); important too is I, 150; *πνεῦμα διατεῖνον* from the *hegemonikon* to the tongue, etc.

¹⁴ See esp. *ibid.* II 879, also e.g. II 836. 861. 866 (for the spider comparison II 879. 236, 12 v. A. see above 157 n. 46).

as Chrysippus developed, or at any rate set forth, his theories after the nerves had been discovered the tenets of his predecessors would be of greater interest to us. We know less about them but what we know suffices to establish a substantial similarity with Chrysippus' theories. Let us note, in any case, that Cleanthes defined the act of walking as *spiritus a principali usque in pedes permissus*¹⁵.

These Stoic doctrines are on the whole well known and have often been described, though less often been seen in the correct historical perspective¹⁶. In regarding the sense functions as activities of the soul the Stoics quite evidently agree with Aristotle and it is almost equally certain that this part of their system reflects his influence—to escape this conclusion it would be necessary to suppose that they only paid attention to the medical authors yet ignored the philosophical presuppositions underlying the medical theories. Still neither in Aristotle nor in the medical authorities was there a precedent for the Stoic identification of the *πνεῦμα* with the deity who pervades and builds up the Cosmos¹⁷. Aristotle never saw a reason for establishing connections between the inborn *πνεῦμα* and the prime mover (the best that he could do about the *πνεῦμα* was to compare the *φύσις* in it to “the elements of the stars”¹⁸; the idea of making the *πνεῦμα* itself a prime mover would probably have struck him as absurd).

Some points of detail are worth recording. The Stoics too know that the senses report to the central organ which combines these reports and deals with them intelligently. This information is contained in a Latin text but we need not doubt that *nuntiare* renders (ἐξ-)ἀγγέλλειν¹⁹, a word which we have repeatedly encountered in the early phases of our subject. The other and no less characteristic verb is *διαδιδόναι*. It too is to be found in the Stoic material. Plotinus in a passage where he summarizes Stoic views²⁰ speaks of the *hegemonikon* as experiencing the sensation (*αἴσθησις*) of a pain which arises in a finger and also mentions that *ὅλη ἡ ψυχὴ τὸ αὐτὸ πάσχει*. He asks how this may come to pass and proceeds to answer in the name of the Stoics: *διαδόσει. παθόντος μὲν πρώτως τοῦ περὶ τὸν δάκτυλον ψυχικοῦ πνεύματος, μεταδόντος δὲ τῷ ἐφεξῆς καὶ τούτου ἄλλω ἕως οὗ πρὸς τὸ ἡγεμονοῦν ἀφίκοιτο*. The doctrine has a very familiar ring for us; the passing on of a sensation from one (part) to the next is bound to remind us of a section in the *Timaeus* analysed earlier in this paper²¹. However the Stoics would not like us to think of their *πνεῦμα* currents as made up of particles.

¹⁵ I 525; see above note 13 for Zeno.

¹⁶ Verbeke's important book (see note 12) pays a good deal of attention to Aristotelian antecedents. In the last century some studies (e.g. Siebeck, *Ztschr. f. Völkerpsych.* 12 [1880], 362ff.) gave consideration to medical antecedents but they did so with exclusive concentration—inevitable at the time—upon the Hippocratics whereas we are now in a position to bring Diocles and Praxagoras into the picture.

¹⁷ See *St. V.F.* I 533; II 310. 1009 (299, 11) al. Cf. Pohlenz, *Die Stoa* I (1945) 73f.; Verbeke 55ff. 61f. and pass.

¹⁸ *De gen. an.* II 3, 737 a 1. Cf. JHS 1957, 119ff.

¹⁹ *St. V.F.* II 879 (235, 36f.; 236, 4. 16).

²⁰ *Ibid.* II 858 (= *Plot.* 4, 7, 7).

²¹ *Tim.* 64b–65a. One may wonder whether the words used by Plotinus reflect sentences of this section (esp. 64 b 5f.) or whether it is rather the case that Stoic doctrine reflects

Epicurus describes soul as "most resembling *πνεῦμα* with an admixture of heat", and in the quadripartite scheme of Lucretius one type of the soul atoms is defined as being "in the nature" of air (*aer*), another in that of wind (*ventus*)²². These doctrines indicate the extent to which Epicurus took account of the prevailing physiological ideas; we may add that Epicurus' "heat" and the *calor* of the third atom group correspond to the "inborn heat" of the medical theory. Yet with the fourth, the *ἀκατονόμαστον*, Epicurus went the *πνεῦμα* theory one better; unlike the Stoics, he did not consider the *πνεῦμα* fine and mobile enough to account for sensitivity and thought²³. As we know, the idea of fine and small soul atoms goes back to Democritus. Epicurus elaborated and modernized it. While he could not accept Democritus' hypothesis of soul atoms and body atoms lying side by side in the organism²⁴—for there must be large intervals between the soul atoms—he agreed with him regarding the initiation of bodily movements. Movement starts in the soul atoms and is from them passed on to the body. Here again the details have become considerably more elaborate. Lucretius gives us a graphic account as to how the movement originating in the atoms of the *animus* is communicated by them to those of the *anima* which are spread *per venas, viscera, nervos*, and from these atoms in turn to those of the body²⁵. We must forego a closer study of these subjects; for the Epicurean position lies somewhat off the road on which we are proceeding. It will, however, have become clear that this system too was by no means immune to the influence of contemporary physiological thoughts and trends.

The fate of the *πνεῦμα* doctrine in Aristotle's own school is considerably more important for our purposes and if here again we report little the reason lies in the condition of our sources. The evidence is lamentably inadequate, vouchsafing no more than occasional glimpses. Theophrastus' extant works are silent on our topics yet we happen to know that in his treatise *On paralysis* (summarized by Photius) he concurred with the medical authorities in looking upon paralysis as a *πνευματικὸν πάθος*²⁶; reporting their views, he said that for some of them the *πνεῦμα* was "altogether responsible for vital heat and movement"²⁷. This goes farther than anything to be found in the testimonies for Diocles and Praxagoras; it shows us in particular that the relation between the *πνεῦμα* and the vital heat

Plato's. Cf. also Verbeke 32 note 73. For Plotinus' own attitude cf. R. Harder, *Entretiens sur l'antiq. class.* 5 (1960) 331f.

²² *Epist. ad Herod.* 63; *Lucr.* III 231ff. Cf. Cyril Bailey, *Titi Lucreti Cari De rer. nat.* (Oxford 1947) II 1025f.; Verbeke 27f.

²³ See esp. *Lucr.* III 241–244.

²⁴ *Ibid.* 370ff. For Democritus see above p. 158.

²⁵ See esp. 4, 877ff.; cf. 3, 143f. 159f. 271.

²⁶ *Frg.* 11, 13 Wimmer (3, 150 Teubner).

²⁷ *Ibid.* 1, 5. The missing word in the clause given to the other school of thought is perhaps not *καταπνυχόμενον* (J. G. Schneider and Wimmer) but *ἐμφοραττομένον*. The blocking of the *πνεῦμα* flow is a thought frequently occurring in the pathology of the time (see below p. 190). "Cooling", to be sure, is the basic principle of explanation in Theophrastus' account; but here something more specific seems needed. (Kalbfleisch made a similar suggestion; cf. Wellmann, *Sikel. Ärzte* 142.)

continued to be discussed, with the *πνεῦμα* tending to gain the ascendancy over the once all-important vital heat. We do not learn whether Theophrastus himself went all the way with this advanced doctrine but it seems to have been his own opinion that if the flow of the *πνεῦμα* is interrupted the blood too ceases to move²⁸. This doctrine represents a step beyond Aristotle (who never refers to the *πνεῦμα* as present in the blood vessels); on the other hand if blood and *πνεῦμα* are supposed to flow in the same channels, Praxagoras' theories were not yet known or not yet accepted in the Peripatos (it is even possible that they had not yet been formulated).

A generation later these theories had become accepted, as we can see from the ('Aristotelian') treatise *Περὶ πνεύματος*, whose author even defends the doctrine of the arteries and of the *πνεῦμα* in them against certain revolutionary new ideas. However, as some of these new ideas reflect the discovery of the nerves, we shall not now enter upon a closer analysis of this treatise—a difficult task in any case because of the author's abrupt and allusive style, although Jaeger has succeeded in reconstructing many of the author's arguments and in finding the point and the targets of his polemics²⁹. Let us merely note that the author knows the *αἰσθητικόν* as well as the *κινητικόν πνεῦμα*³⁰. The former he does his best to confine to the arteries insisting *τὴν ἀρτηρίαν μόνον εἶναι δεκτικὴν πνεύματος* and (*τὴν ἀρτηρίαν*) *μόνον αἰσθάνεσθαι*³¹; as for the latter he would be willing to find it operating in the sinews³², partly, it seems, or perhaps even wholly for the reason that they are *νεῦρα* and that he has more confidence in them than in the newly discovered nerves for which the same word is used.

The only other Peripatetic here to be mentioned is Straton. In the testimonies for his psychology we read that the pain *διαδίδοται* (or *ἀναφέρεται*) from the organ affected to the *hegemonikon*—which Straton rather heretically placed in the forehead between the eyebrows—and that the soul "is pulled" to the place in the body where the suffering originated³³. The pneumatic nature of the soul is not directly attested but may be inferred, e.g. from the comparison preserved by Tertullian of soul with a *flatus in calamo* (flute)³⁴. As the *flatus* emerges at the openings of the flute so does soul at the sense organs. There is every reason for agreeing with Wehrli's observation³⁵ that the comparison receives its point from the definition of soul as *πνεῦμα*.

²⁸ Ibid. (last sentence).

²⁹ Hermes 48 (1913) 55ff.

³⁰ 5, 483 a 24ff.; 8, 485 a 7.

³¹ 5, 483 b 12. a 24. See also the disquisitions a 24ff. and 30–b 12 with Jaeger's comments loc. cit. 68.

³² 8, 485 a 6 (he says *νεῦρα ἢ τὸ ἀνάλογον*).

³³ Fritz Wehrli, *Die Schule des Aristoteles* 5 (Basel 1950) frg. 111; cf. 119f. as well as 74, 108–110 and for Straton's lost *Περὶ πνεύματος* Wehrli on 106.

³⁴ Ibid. frg. 108. Wehrli (in his commentary) offers the interesting suggestion that for Straton the soul moves in the *κοιλία* of the blood vessels. If this is correct, Straton would follow the medical authorities more closely than the Stoics did. Given his close connections with Diocles and Erasistratus (Jaeger, *Scripta Minora* 195ff. 233 and pass.; Diels, S.B. Berl. Ak. 1893, 111) we should be quite ready to believe this. See however the next pages.

³⁵ Ibid. on frg. 108.

Thus the evidence, fragmentary as it is, attests a continuing and indeed even an increasing concern of leading thinkers with our problems. Still there is one question on which we should wish to have more definite information. Did physicians like Diocles and Praxagoras explain how and by what channels the sense perceptions reach the central organ? The testimonies offer no answer. That these men had the concept of a central organ is certain; as for the communication of this organ with the senses, it is reasonable to think that they followed up the suggestions which had been advanced by Aristotle. One might even argue that if Aristotle in the generation before them, the Stoics as their contemporaries, and Herophilus and Erasistratus immediately afterwards had theories regarding this communication a physician of Praxagoras' stature must also have known how the *πνεῦμα* reaches the organs of sense. Did he then assign this function to the arteries? In the absence of specific evidence it is tempting to indulge in speculative arguments but the simple truth is that we do not know the facts³⁶. All that we can say is that Praxagoras must have been familiar with the problem; yet, being a 'professional' and thereby prevented from treating physiological considerations in the same cavalier spirit as the Stoics, he may well have discussed the problem as problem. In this case Herophilus would find himself confronted with an *ἀπορία* for which the philosophers had their solutions but for which no physiologically satisfactory answer had yet been found (we should beware of ruling out a situation so full of incentive for a new search). To sum up, we cannot decide whether the sensory nerves were the first hypothesis advanced by a medical authority or whether they were a better hypothesis designed to replace a less satisfactory one. In the parallel question—to be answered by the discovery of the motor nerves—the evidence suffices to show a continuity of solutions not only on the part of the philosophers but also of the medical thinkers.

V. The Discoverers

We know considerably more details about Erasistratus' than about Herophilus' investigations. Intelligent guesses must help to reconstruct the chronology of their lives and of their discoveries¹, while in questions concerning their personal,

³⁶ For the reasons indicated above (p. 179 note 2) the rather detailed account of the physiology of the sense functions in *Anon. Vind.* 17–20 (219, 9ff. Wellmann) can no longer be treated as evidence for Diocles. It gives the impression of using Stoic physiological psychology and incorporating also some results of Herophilus' anatomical work on the eye. However, what strikes us as Stoic may be derived from the "pneumatic school" (see Wellmann, *Die pneumat. Schule* [Berlin 1895] 142). As for Praxagoras, if one wishes to speculate, one would start from the fact that veins were known to reach the sense organs (*Arist. Hist. an.* III 3, 514 a 8f. 21f.) and argue that the arteries, since they were correctly held to parallel the course of the veins (*παράκειται De spir.* 5, 483 b 30f.; cf. *Arist. ibid.* 23ff.) must likewise end in these organs.

¹ The pivot of the chronology is Erasistratus' *floruit* (258/7). For a judicious treatment of the tradition about his life and doctrines see Max Wellmann, RE s.v. Cf. further R. Fuchs, *Erasistratea* (Diss. Lpz. 1892) and *Hermes* 29 (1894) 171ff., esp. 180–183; Verbeke, *op. cit.* 176ff.; Jaeger (see above p. 178 note 1). F. J. Dobson, *Proc. Roy. Soc. Med.* 20 (1926/7) 825ff. does not carry the analysis far enough. For Herophilus we are less well off.

professional, or scholarly relations no help at all is available. Still it seems certain that Herophilus was the actual discoverer of both sensory and motor nerves², but since Erasistratus carried the inquiry considerably farther and supplied information that Herophilus had not been able to ascertain, his startling achievements put the work of his precursor in the shade.

Thus it was Herophilus who after so many ingenious theories and speculations actually identified the entities through which the soul partakes in the processes of sense perception and of bodily movement. It was—essentially—one and the same organ which provided the answer to both questions. Looking back at the history of these questions we may point to Aristotle as the first thinker who formulated both questions in psychophysical terms and who for both of them resorted to the same principle of explanation. In the period between him and Herophilus the *πνεῦμα* had advanced to a central place in physiology and had become the instrument of soul. Though in the Epicurean scheme only present by proxy and though not by every other thinker applied to both questions, it clearly formed an important link between the two subjects. Herophilus' discovery proved that those who had looked for an identical answer were right. But to say this is to emphasize one aspect of the story unduly and to the detriment of another. The men who kept the two subjects together actually prepared the ground for Herophilus' own work and were in a very real sense his precursors.

As we are not writing a history of Greek physiology we need not present the entire evidence bearing on Herophilus' and Erasistratus' discoveries. But the perspective in which we look at their doctrines is indeed an historical one and what interests us particularly is the links with such earlier theories as had been devised to take care of the same problems. *Pedetemptim progredientes* we may begin with a passage in Galen's *De tremore*³: μέμφομαι ... Πραξαγόρα καὶ Ἡροφίλῳ, τῷ μὲν ἀρτηρίων πάθος εἰπόντι τὸν τρόπον, Ἡροφίλῳ δὲ φιλοτιμονμένῳ δεῖξαι πρὸς τὸ νευρῶδες αὐτὸ γένος ἀεὶ συνιστάμενον ... Ἡρόφιλος ἡπατήθη τὸ τῆς δυνάμεως πάθος ἀναφέρων τοῖς ὀργάνοις· ὅτι μὲν γὰρ τὸ νευρῶδες γένος, οὐ τὸ ἀρτηριῶδες ὑπηρετεῖ ταῖς κατὰ προαίρεσιν κινήσεσιν ὀρθῶς ἐγίνωσκεν (his error consisted in regarding τὸ σῶμα τῶν νεύρων as αἴτιον κινήσεως, in truth the κινούσα αἰτία is ἡ διήκονσα δύναμις διὰ τῶν νεύρων). Little comment is needed; we need only to remember that Diogenes and Aristotle had used the *πνεῦμα* in the physiology of voluntary movement and that Praxagoras had specified the arteries as the channels through which

² According to Ruf. *De corp. part. anat.* 71–74 (184, 13ff. Ruelle) Herophilus knew not only sensory but also motor nerves. The latter he called *προαιρετικά* (not as Erasistratus preferred to call them, *κινητικά*; Ruf. *De nom.* 211 mentions a third name: *πρακτικά*). Ruf. *ibid.* 74 gives the impression that Herophilus did not make a clear cut distinction between the motor nerves and the *νεῦρα* connecting bone with bone or muscle with muscle. The latter are clearly sinews and it would be conceivable that the discoverer of the nerves did not completely realize the difference between them and the sinews; cf. Max Neuburger, *Geschichte d. Medizin* (Stuttg. 1906) II 263.

³ *De tremore* 5 (7, 605 K.).

ἡ κατὰ προαίρεσιν κίνησις ἐπιπέμπεται τῷ σώματι⁴. The passage of Galen shows with all desirable clarity how Praxagoras' pupil transferred to the nerves the function which his master has assigned to the arteries⁵. To put the matter differently, one generation recognized the arteries as physiological entities *sui generis*, and the next generation did the same with regard to the nerves, both being prompted by the desire of finding how ἡ κατὰ προαίρεσιν κίνησις ἐπιπέμπεται. Good fortune has preserved Herophilus' actual term for the motor nerves; he did not, like Erasistratus, call them κινήτικα νεῦρα but προαιρετικὰ νεῦρα⁶. Quite another question is how much weight we are to give to Galen's criticism. Clearly Galen, being unable to forget his own strong views about the δυνάμεις, makes an alarming difference of doctrine of what in itself was merely a preference for different terms. Herophilus cannot possibly have thought of the motor nerves as producing movement "by themselves"; if such were his views why would he have associated these nerves with προαίρεσις, traced them to their origin in the brain and in the spinal marrow, and declared one ventricle of the brain—that of the cerebellum—as the "most important"? Did Galen find him unwilling to assume the presence of soul πνεῦμα in the motor nerves? Improbable as this is, we must admit that the evidence for Herophilus includes no direct testimony either for or against the presence of πνεῦμα in the motor nerves. This is the more regrettable as the πνεῦμα has become a kind of *Leitfossil* for our study of continuity. However we shall presently find incontrovertible proof that it survived into the new phase of physiological theory, and the evidence, when considered in its entirety, makes it practically certain that Herophilus thought of the πνεῦμα as operating also in the motor nerves.

Let us now consider Galen's testimonies for Herophilus' conception of the sensory nerves. In *De usu partium*⁸ we read: τῶν ἐπὶ τοὺς ὀφθαλμοὺς ἀπ' ἐγκεφάλου κατιόντων νέρων τῶν αἰσθητικῶν, ἃ δὴ καὶ πόρους ἀνόμαζεν Ἡρόφιλος ὅτι μόνοις αὐτοῖς αἰσθηταὶ καὶ σαφεῖς εἰσιν αἱ τοῦ πνεύματος ὁδοί, ὥσπερ αὐτὸ τοῦτο [τὸ] παρὰ δόξον καὶ ὑπὲρ τὰ λοιπὰ τῶν νέρων ἐστὶν οὕτω ... (what follows has no bearing on Herophilus). We can make one point slightly clearer than Galen makes it. If Herophilus was in the habit of calling the optic nerves "paths" (πόροι), instead of using the technical name νεῦρα, he merely retained for the reason stated by

⁴ See above pp. 178 and 179.

⁵ In Galen's statement—as distinct from his polemical comments—every word counts. We need not doubt that Herophilus put much zeal in his proof that "in every case" (or "without exception") the nerves were the affected organ; φιλοτιμεῖσθαι may even imply that he polemized against Praxagoras, although we should need the addition of πρὸς αὐτόν to regard this as certain. For Praxagoras as teacher of Herophilus see esp. Gal. *Meth. med.* I 3 (X 28 K.); *De diff. puls.* IV 3 (VII 723).

⁶ See above p. 185 note 2. Wellmann loc. cit. 343 misunderstood the Rufus passage; as we have seen (*ibid.*), it does not indicate that Herophilus was ignorant of the motor nerves but that he called them by a name which did not remain in use—and which shows his connection with the Peripatetic tradition. For his interest in προαίρεσις see also Ruf. *De puls.* 2 (221 Ruelle).

⁷ Gal. *De usu part.* VIII 11 (III 667 K.); Aet. IV 5, 4 is a senseless conflation.

⁸ X 12 (III 813 K.).

Galen the word under which these paths had been familiar to Aristotle and others⁹ long before nerves were identified as peculiar or specific entities. We do not know for certain whether Alcmaeon too had used the word *πόρος*. Yet he had certainly spoken of passages between eyes and brain (and may well have found them anatomically)¹⁰. After many *ambages* physiological research has found its way back to his pioneering achievements.

Still what interests us most is not Herophilus' name for, but his conception of these "paths". As we learn from Galen, he thought of them as containing *πνεῦμα*, or more precisely *αἰσθητικὸν πνεῦμα*. Here we certainly have the continuity for which we are looking. Another passage in Galen states the reason why the optic nerve recommended itself to Herophilus as a particularly suitable (or obvious) carrier of *pneuma*: *δοκεῖ δέ μοι τὸ ἀπ' ἐγκεφάλου καταφερόμενον ἐπὶ τὸν ὀφθαλμὸν νεῦρον, ὃ δὴ καὶ πόρον ὀνομάζουσιν οἱ περὶ Ἡρόφιλον ὅτι τούτου (τοῦτο codd.) μόνον φανερόν ἐστι τὸ τρημα, πνεύματος ὑπάρχειν ὁδὸς αἰσθητικοῦ*¹¹. Herophilus had in his *Ἀνατομαί* found out that these strings were hollow¹².

What then was Herophilus' opinion regarding the presence or absence of *πνεῦμα* in the other sensory nerves? We must be very careful to make the right use of Galen's two testimonies. He does not say that Herophilus found *ὁδοί* of the *πνεῦμα* only in the optic nerves but that here only were these 'ways' visible and clearly present (*αἰσθηταί, σαφεῖς*) and that here only was the perforation (*lumen, τρημα*) to be seen. What is visible is certainly real but the conversion of this proposition, scil. that everything real is visible would not be accepted by the medical researchers of this period (who were also 'thinkers'). Like the atomists and indeed all physicists and physiologists, they were quite prepared to reckon with realities not accessible to the senses. We even happen to know what term they used for such realities. They are *λόγω θεωρητά*¹³. Thus the most natural and methodical inference from Galen's statements is that the *πνεῦμα* in the other sensory nerves was for Herophilus a *λόγω θεωρητόν*, something whose presence was to be inferred by reason. The alternative hypothesis would be that he suspended judgment but this hypo-

⁹ Esp. *De gen. anim.* II 6, 744 a 8 (for other passages see *Ind. Arist.* 623 a 47 ff.).

¹⁰ *Vorsokr.* 24 A 5, 26; A 10. The latter testimony (A 10) appreciates Alcmaeon as a forerunner of Herophilus but the anatomical information which it offers is a summary of Herophilus' achievements. However by combining A 5, 26 and A 10 we arrive at the conclusion that Alcmaeon had identified the *πόροι* from the eyes to the brain. For a skeptical opinion see above p. 152.

¹¹ *De sympt. caus.* I 2 (VII 89 K.).

¹² Modern physiologists find this difficult to believe and doubt whether Herophilus really made his observation on human bodies; see the hypothesis of the ophthalmologist J. Hirschberg reported by Wellmann, *Fragm. d. sikel. Aerzte* (p. 178 n. 1) 48 note 4. Other hypothetical explanations have been suggested to me by experts but none of them with sufficient confidence and encouragement to warrant recording. Galen himself completely agrees with Herophilus on this point (e.g. *De usu part.* VIII 6; III 639 ff. K.; XVI 3; IV 275 ff. K.).

¹³ Cf. *Aet.* I 23, 6 and also the use of the term in *Anon. Lond.* 13, 28; 30, 52; 31, 15 et al. (see also Epicurus *Ad Herod.* 47. 62). Herophilus' methodological principle quoted *ibid.* 21, 22 shows that he started with the *φαινόμενα* but thought it necessary to go beyond them. See also Wellmann, *RE s.v. Erasistratus* 337.

thesis is supported neither by Galen's words nor by a general consideration of historical probabilities. As we know, the concept *αἰσθητικὸν πνεῦμα* was in the air. It must have been familiar also to Praxagoras, who had been Herophilus' teacher, though whether or not he had actually identified the channels of this *πνεῦμα* is a question better left open¹⁴.

Erasistratus' corresponding doctrines need not be 'reconstructed'; here our sources speak clearly and at times even present us with his own words. Thus Galen quotes his basic explanation of paralysis; Erasistratus said it was caused by "moist matter" entering "the receptacles of the *πνεῦμα* in the nerves". In this connection he described the nerves themselves as *δι' ὧν αἱ κατὰ προαίρεσιν κινήσεις συντελοῦνται*¹⁵. Thus, after Diocles, Praxagoras and Herophilus, Erasistratus too has his say about "voluntary movement"; he too has looked for the means and channels (the *δι' ὧν*) through which the decisions of our mind are communicated to the body so as to be realized in actions. The great physicians have certainly been conscientious in dealing with Aristotle's legacy¹⁶.

But did Erasistratus adhere to the *πνεῦμα* theory to the end of his life? According to some of our trusted books and articles¹⁷ he renounced it in his old age, after he had dissected the human brain, and declared that the nerves contained not *πνεῦμα* but marrow or brain substance. This change of theory would have been a decision of the greatest consequence not only for his own system but for the future of Greek physiology. Professor Verbeke, who is one of the scholars ascribing to Erasistratus this fundamental revision of doctrine, rightly remarks¹⁸ (185) "cette découverte a du renverser de fond en comble les conceptions pneumatologiques d'Erasistrate: en effet, quel rôle faut-il désormais attribuer au pneuma psychique contenu dans le cerveau, s'il ne pénètre plus les nerfs pour commander toute l'activité de connaissance et de mouvement libre de l'homme"? We should indeed be at a loss for an answer. Fortunately we need not rack our brains to find one. Although the story about this fundamental change of doctrine seems on the point of becoming the vulgate it rests on a patent misunderstanding of the text.

The text in question¹⁹ consists of a verbatim quotation from Erasistratus in which he does announce some new and significant insights and of the comments—partly explanatory, partly critical, and all of them well meant—by which Galen helps us to appraise these new thoughts. Erasistratus' own words, let it be said

¹⁴ See above p. 184.

¹⁵ Gal. *De melanch.* 5 (5, 125 K.). In Kühn's text ἀγγεῖα τοῦ πνεύματος ἐν τοῖς νέρουσιν the word *πνεύματος* is evidently a mere misprint for *πνεύματος*. Cf. *Anecd. med.* in Rh. Mus. 49 (1894) 550; Wellmann, loc. cit. 345.

¹⁶ With the exception of the last (11) chapter, the subject of *De anim. mot.* is voluntary movement; for *proairesis* see ibid. chap. 6, 700 b 17ff.

¹⁷ Wellmann loc. cit. 343f.; Verbeke, op. cit. 185; see also the (rather vague) statement in Charles Singer, *The Evolution of Anatomy* (London 1925) 32; Max Neuburger, op. cit. (note 2) 267.

¹⁸ See preceding note.

¹⁹ *De Hipp. et Plat.* VII 3 (V 602–604 K.; 598–600 Mü.).

at once, assert nothing at all about the substance or the content of the nerves. His new discoveries relate not to the content but to the starting point of the nerves; having previously thought of them as originating in the meninx (or dura mater), he has now traced them into the interior of the brain and has, in particular, discovered the point of origin for each type of the sensory nerves²⁰. Galen, helpful as always, explains—even before he begins to quote Erasistratus—that each nerve has an inner part as well as two envelopes. The inner part he—i.e. Galen—compares to the pith or heartwood of a tree: τὸ μέσον μὲν [τοῦ] αὐτοῦ καὶ διὰ βάρους, ὅπερ ἀνάλογόν ἐστι τῇ τῶν δένδρων ἐντεριώνῃ²¹. Taking up this analogy a few sentences later, Galen says that when Erasistratus in his old age had leisure for research and made his dissections “more accurate” (ἀκριβεστέρας ἐποιεῖτο τὰς ἀνατομάς) he ἔγνω καὶ τὴν οἶον ἐντεριώνῃ τῶν νεύρων ἀπ’ ἐγκεφάλου πεφυκέναι²² (what he found out about the ‘envelopes’ is not reported and it was after all Galen who introduced this concept). What has misled the interpreters is the word ἐντεριώνῃ. To rid ourselves of this unfortunate misunderstanding, it will now suffice to point out that it is not the word for marrow—which is μυελός—, that it is introduced by Galen, that it is on both occasions clearly and honestly marked by him as a comparison or “analogy”, and that it carries no implication whatever for the substance of the nerves. Must we still add that even if in some mysterious way it referred to the substance (which not even for Galen, let alone for Erasistratus, is the point at issue) it could not interfere with the πνεῦμα since this is in any case λόγῳ θεωρητόν and the best kind of evidence that Erasistratus could hope to find for it would probably correspond to that recorded by Herophilus²³? Thus we may dismiss the worry that Erasistratus in his old age saw his pneumatology and with it a good part of his physiology crumble “de fond en comble”; in the light of all that we know it remained unshaken to the end of his life and the psychic πνεῦμα continued to be passed out by the brain—indeed now from the inner part of the brain, which is a much more satisfactory idea²⁴—to the nerves. Yet Erasistratus also endorsed, and indeed defended vigorously, Praxagoras’ theory that the

²⁰ Ibid. (602 ex. K. 600 M.). The passage lifted from Erasistratus’ treatise begins with the words ἐθεωροῦμεν δὲ καὶ τὴν φύσιν τοῦ ἐγκεφάλου (φύσις = structure). We have no choice but to accept it as fact that Erasistratus had not opened the human brain before he was a γέρον and had leisure for scientific research (must not Herophilus too have opened the brain if he knows about its ventricles?). Galen may even have taken these biographical items from the “Introduction” of Erasistratus’ treatise; at least it is difficult to imagine where else he may have found them. For the origin of the nerves see below p. 193. Some doxographers offer the ridiculous statement that meninx and cerebellum were for Erasistratus identical, a patent conflation of his earlier and his later views (Diels, *Doxogr.* 208f.).

²¹ Ibid. (602, 4ff. K.; 598, 7 M.). The meaning of ἐντεριώνῃ is correctly stated in L.&S. Theophr. *H. pl.* III 17, 5 (cited in L.&S.) provides the best illustration for it.

²² Ibid. (602, 16 K.; 599, 2 M.).

²³ See above p. 187. There can be no doubt that Erasistratus’ physiological system included invisible and λόγῳ θεωρητά parts of the organism; see e.g. Gal. *De nat. fac.* II 6 (II 104f. K.); *Anon. Lond.* 21, 25; 33, 51 (39, 22?).

²⁴ Cf. Gal. *De Hipp.* VII (606 K. 603 M.). 608: εὐλογον οὖν γεννᾶσθαι μὲν τοῦτ’ τὸ πνεῦμα κατὰ τὰς κοιλίας τοῦ ἐγκεφάλου (in its context this statement presupposes some of Galen’s own observations; I quote it nevertheless because we know that κοιλίαι are welcomed by the pneumatists and that Erasistratus on opening the brain found its four κοιλίαι).

arteries are filled with *πνεῦμα* which they receive from the heart (more precisely from the left ventricle of the heart, while the right ventricle supplies the veins with blood). In fact the brain too, according to his view, is given its *πνεῦμα* by the heart and receives it by way of the arteries. Erasistratus called the *πνεῦμα* in brain and nerves *πνεῦμα ψυχικόν*, thereby distinguishing it from the *πνεῦμα ζωτικόν* in heart and arteries²⁵. If Erasistratus had changed or given up his doctrines regarding the psychic *πνεῦμα* it would be difficult to explain the prevalence of these doctrines throughout many later centuries. Not only Galen but even Descartes still knows the *πνεῦμα* which flows through the nerves, and the *Encyclopédie*, being far from renouncing this idea, offers the suggestion that the “*esprits animaux*” or “*esprits vitaux*” in the nerves may be “*un feu subtil*”^{25a}.

We have already had occasion to compare Praxagoras' and Herophilus' explanations of tremor²⁶. Thanks especially to the invaluable *Anecdota medica* published in 1894 by R. Fuchs²⁷ we are able to extend the comparison to some other diseases and to realize to what extent the newly discovered instrument of psychic control takes over the functions previously assigned to the arteries. Observations of the kind will substantiate our thesis of historical continuity even though we are not in these instances looking far back into the past but content ourselves with seeing what changes—and what remains unchanged—in the transition from one medical school to the next or second in succession. Let us however, while we examine the evidence, bear in mind that already our Hippocratic author defined epilepsy as a blocking of the air passages by phlegmatic material²⁸. Doubtless the Hellenistic physicians would smile at his ignorance regarding the ways by which the air enters the body as well as those by which the *πνεῦμα* is distributed in it. And yet in some respect they have returned to his position; for the *πνεῦμα* is no longer ‘inborn’ (as it had been for Aristotle) but is once more thought of as acquired by the process of respiration.

Diocles, Praxagoras, and Erasistratus are agreed in tracing apoplexy to an

²⁵ Cf. Gal. *De usu resp.* 5 (IV 502 K.); *De diff. puls.* IV 7 (VIII 760 K.); *An sang. in art.* (pass). For the two kinds of *πνεῦμα* see in particular Gal. *De Hipp. et Plat.* II 8 (V 281 K. 245 Mü.). We should like to know whether Erasistratus thought of the *ψυχικόν πνεῦμα* as qualitatively different and if so how he explained the difference.—Incidentally, does not *ventus vitalis* in Lucr. III 128 create the presumption that Epicurus knew and used the concept *ζωτικόν πνεῦμα*? Many phases of Erasistratus' pneumatology are of necessity omitted in my account; see for them Wellmann, loc. cit. 340ff. and Leonard G. Wilson, *Bull. Hist. Med.* 33 (1959) 293ff. It should however be mentioned that Erasistratus also had definite theories regarding the function of the muscles in the realization of bodily movement (Gal. *De loc. aff.* VI 5; VIII 429 K.; *An in art. nat. sang.* 2 [IV 707 K.]). They too have their place in the context of *προαίρεσις* yet the primary agent of *προαίρεσις* is for him clearly the motor nerves.

^{25a} s.v. *esprit* (also s.v. *nerfs*). See Descartes, *Disc. de la méth.* V (VI 54f. Adam-Tannery); *Les passions de l'âme* I 7, 10. 31. 34, etc. The doctrine of ‘animal spirits’ was rejected by Thomas Reid in his *Essay on the Intellectual Powers* II 3 (1785). I owe this reference to Professor Julius Weinberg.

²⁶ Above p. 185.

²⁷ *Rh. Mus.* 49 (1894) 532ff.

²⁸ Cf. above p. 155. Plato's conception of illnesses attacking the soul (*Tim.* 86 b ff.) is altogether different.

accumulation of phlegmatic material. But while the former two hold that this material collects in the arteries and interferes with their function, Erasistratus localizes the affection in the brain and in the nerves which when filled with this phlegmatic stuff are no longer able to "receive psychic pneuma"²⁹.

Diocles regarded phrenitis³⁰ as an inflammation of the diaphragm. Praxagoras too defined it as an inflammation but differed from Diocles in that he regarded the heart as the affected organ since for him φρόνησις is the activity (ἔργον) of the heart. Contrast Erasistratus who agrees only that οὗ τόπου ἡ νόησις φρόνησίς ἐστι τούτου ἡ παρανόησις παραφρόνησις ἂν εἴη but "remaining consistent with his opinions" holds that the disease arises in the meninx of the brain³¹.

To the new doctrines concerning the causes of paralysis reference has been made earlier but we have not yet mentioned that Erasistratus distinguished between a paralysis affecting the entire body and one limited to specific parts of it³². Still his explanation was in both cases the same; the disease is always caused by the entering of moist substance into the *lumina* (κοιλώματα) of the nerves and by the resulting interference with "voluntary movements" or—the same idea differently worded—with the "faculty sent down by the ruling organ" (ἡ καταφερομένη δύναμις ἀπὸ τῆς ἀρχῆς)³³. Diocles and Praxagoras, we remember, had likewise understood paralysis as a disturbance of voluntary movement but had assigned its origin to the vessels (arteries) starting in the heart and in the thick artery³⁴.

It is noteworthy that in all instances here discussed a part of the explanation remains unaltered. What changes is the identification of the instrument used by the soul to bring about voluntary motions.

As Herophilus and Erasistratus followed up their discovery they soon found themselves in a position to solve still another problem of long and central standing in physiological thought and of no small importance for philosophy as well. In the course of our inquiry we have from time to time made reference to changing convictions regarding the localization of the central organ. A more coherent or systematic exposition might have been desirable but would inevitably have cut

²⁹ *Anec.* (see n. 27) 542f.

³⁰ Defined in L.&S. (not quite fairly, as we shall see) as "inflammation of the brain". Diocles' explanation, although it seems to have been somewhat more complex than I here represent it, evidently keeps closest to the meaning of φρήν (for the history of this word cf. R. B. Onians, *Origins of European Thought* [Cambridge 1954] 23ff.); see also *Anec. med.* 14.

³¹ *Anecd.* 540f.; for the meninges see above p. 189.

³² *Ibid.* 550. For Erasistratus two books on paralysis are attested (see Wellmann 350).

³³ *Ibid.*

³⁴ *Ibid.*; see above p. 179. We do not know Erasistratus' explanation of epileptic conditions. Only the doctrines of Hippocrates, Diocles, and Praxagoras are reported *Anecd.* 541; however in the summary of Hippocrates' views *ibid.* reference is made to conditions of the nerves, a patent anachronism which makes one wonder whether some doctrines here ascribed to Hippocrates are not actually those of Erasistratus; the doxographic material may well have passed through a process of injudicious shortening. Note also that Diocles and Praxagoras are cited in the *Anecdota* for explanations of mania and melancholia and the latter even for a theory regarding (religious) ἐνθουσιασμός whereas for Erasistratus no corresponding information is available.

across other lines of historical development. A brief résumé may make up for this omission. Alcmaeon, the author on the Sacred Disease, Plato and—with a difference, it would seem—Straton localize the organ of ultimate control in the brain. Empedocles, Democritus, Aristotle, Diocles, Praxagoras, Stoics, and Epicureans are all of them *θατέρον τρόπον*, holding that “thought”, “soul” or “mind”—or whatever term and definition they employ for the central organ—has its seat in the heart (or in any case, in the chest). Plato, it will be remembered, conceded an important role to the heart; on the other side there is some indication that Diocles allowed the brain some kind of place in the scheme of psychic functions³⁵. We may assume that in the measure in which philosophical and physiological theory developed the arguments in both camps increased in number as well as in sophistication. Fortunately, as far as we can see, the bitterness did not increase correspondingly, even if some champions of the heart theory regarded the alternative opinion as below contempt. Speaking broadly, we know the main reasons adduced by Aristotle, Epicurus, and Chrysippus in defense of their positions³⁶ (however, by strict canons Chrysippus ought not to be mentioned here since he built up his battery of syllogisms only after the discovery of the nerves and probably in reaction against it).

In any case it is evident that the party favoring the brain was a minority. Making allowance for whatever specific doctrine lies concealed behind the cryptic testimony for Diocles, we may yet say that Straton is the only thinker of note in the first half of the third century who approximated the ‘truth’—and can we, in view of the connections between him and Erasistratus, be quite sure that he arrived at his divergent opinion without the benefit of the new discoveries? These discoveries decided the controversy in favor of the minority opinion. On the basis of his dissections Herophilus showed clearly and for everybody who could appreciate empirical evidence irrefutably that the nerves originated in the brain. Once this was realized the investigations concentrated on a more precise identification of the place or part of the brain to which each kind of the nerves is attached. Here the lack of further information regarding Herophilus’ procedures and conclusions is particularly to be regretted. The only additional item known is that he specified the “fourth ventricle”, or the ‘cavity’ of the cerebellum, as seat of the *ἡγεμονικόν*³⁷.

Erasistratus, in giving an account of his own observations³⁸, was under no obligation to indicate how far Herophilus had anticipated him; the memorable passage which Galen has lifted from this account merely sets forth what he saw when *θεωρῶν τὴν φύσιν τοῦ ἐγκεφάλου*. The items mentioned in it include three ventricles in the cerebrum and one in the cerebellum, the membranes or meninges of both, and the windings or convolutions of both. The convolutions (*ἐλγμοί*) of the cerebellum prompted his comment that “just as other animals, such as deer

³⁵ See above pp. 163ff. 179 (Diocles frg. 44 Wellm.).

³⁶ Arist. *De part. an.* II 7, 652 a 24ff.; Lucr. III 140ff.; for Chrysippus see below p. 195.

³⁷ Ruf. *De anat. part.* 74; Aet. 4, 5, 4; Gal. *De usu part.* IX 1 (III 667 K.).

³⁸ See above p. 188 note 19.

and rabbit or if any other surpasses the rest in the swiftness of its running, are well provided with organs useful for this purpose, to wit muscles and sinews, so in man, since he surpasses the other living beings in the power of thinking (*διανοεῖσθαι*), this part has far more convolutions (*πολὺ τοῦτ' ἐστὶ <μᾶλλον> πολύπλοκον*)³⁹. Thus he evidently, like Herophilus, placed the *hegemonikon* or organ of thought in the cerebellum. In the cerebrum, on the other hand, he found the *ἀποφύσεις τῶν νέρων* and therefore declared it to be the *ἀρχὴ τῶν κατὰ τὸ σῶμα*. "For the perception coming from the nostrils had a passage leading to (the *ἐγκέφαλος*) and so had that from the ears. Yet to the tongue and to the eyes too there were connections (? *ἀποφύσεις*)⁴⁰ from the brain."

Now that we have traced the 'unbroken' history of our subject and have given due relief to the contributions of the philosophers, fairness demands that we recognize the decisive part which 'empiricism' had in the final solution of the two great problems. It was not by speculation or by logical reasoning that the nerves were identified as carriers of sensation and instruments of movement but by the empirical method of dissection and by the inspection of the dissected material. The passage preserved verbatim from Erasistratus states simply what he saw. But would the great empiricists and researchers have conceived the idea of a ruling and central organ? One may doubt it. To be sure, the author of the treatise on the Sacred Disease made some progress toward understanding the role of the brain but there can be no doubt that the problems concerning the relation between the senses and the center were brought into much sharper focus by Plato and Aristotle. Nor should we forget that the empirical method was proclaimed, extolled, and practiced by Aristotle. After Cos—and, perhaps, Sicily—the Peripatus had been the home of empirical research in biology, as well as in other subjects. As regards anatomical research in particular, we cannot say with certainty where and by whom it was begun. In the tradition Alcmaeon and Diocles compete for the great distinction of being the first anatomists⁴¹. Alcmaeon's claims have been disputed; as for Diocles, he cannot have been the first unless he was the anatomist of the Peripatus. The numerous references to the *ἀνατομαί* in Aristotle's zoological treatises speak an unmistakable language⁴². In fact it is

³⁹ The text of Erasistratus' sentences is unfortunately disfigured by a good number of corruptions, and a classicist even if his fingers are itching must not rashly attempt to emend it; however, Gal. *De usu part.* VIII 13 (III 673 K.) where Galen evidently paraphrases the same passage of Erasistratus should help us to improve the quotation in *De Hipp. et Plat.*, as it has probably helped Iwan Müller to make his text so much better than Kühn's. I accept Müller's addition of *μᾶλλον* 600, 4 (which the parallel passage supports) but should in 600, 1 put a comma after *ὑπεραίρει* and continue *τοῖς πρὸς ταῦτα χρησίμοις ἐν κατεσκευασμένον ἐστὶ (κατεσκευασμένοις codd.) μὴσί τε καὶ νέρους*. In 600, 2ff. I should read *οὕτω καὶ ἀνθρώπων (καὶ ἀνθρώπος codd., καὶ ἀνθρώπων Müller) ... πολὺ <μᾶλλον add. Mü.> τοῦτ' ἐστὶ πολύπλοκον*. Müller's changes in the last three words are unnecessary.

⁴⁰ *ἐφέροντο ἀποφύσεις*. Having read shortly before this about *ἀποφνόμενα νέρους* (598, 6. 13) we may think that we understand *ἀποφύσεις* but it seems to have a precise technical meaning.

⁴¹ See *Vorsokr.* 24 A 10 and Diocl. frg. 23 W.

⁴² Cf. *Ind. Arist.* s.v. *ἀνατομή* and also 104 a 4ff.

very probable that Aristotle himself saw and examined the passages from the eyes to the brain which he mentions in *De generatione animalium*⁴³. But his theory prevented him from accepting them in the important function which Alcmaeon had assigned to them. The only part of the body in which the faculties of soul could be centralized was the heart. True as it is that in the psychophysics of the Peripatus theory and empiricism were brought into a relation of mutually beneficial cross-fertilization, in this instance the theory clearly was too firmly entrenched⁴⁴. Another forty years of intensive research had to pass⁴⁵ before the impact of empirical research was strong enough to break down the theory⁴⁶.

We may conclude our historical study by briefly taking account of three contemporary reactions to the epochmaking discovery. The reaction of the Peripatus, or at least of one important member of it, is again to be found in the treatise *De spiritu*. Here we have every excuse for brevity since Jaeger in the course of his analysis identified most targets of the author's polemical remarks⁴⁷ (and a good part of the polemic concerns subjects other than those here studied). The news of the startling developments in the Alexandrian laboratories were far from welcome to Erasistratus' "old school"; the little treatise shows vividly into what confusion and conflict of feelings the new ideas plunged a mind steeped in Peripatetic orthodoxy. It may be pleaded that the author's information was incomplete; he has heard something of the Erasistratean *triplokia* of vein, artery and nerve⁴⁸ but tries to accept the word *νεῦρον* in its traditional meaning (= sinew) and to console himself with the thought that there are *νεῦρα* in the heart (a safe doctrine backed by Aristotle's authority). If the *νεῦρα* are sinews he is quite willing to let them carry *κνητηκὸν πνεῦμα*⁴⁹. We have already recorded that the arteries remain for him the only organ of sensitivity⁵⁰. As for the brain, the author knows of men who consider it the *ἀρχή* but sees no need to comment on this opinion⁵¹. He himself would rather regard the *πνεῦμα* in the arteries as 'soul'; for if it is not actually soul it must in any case be closely linked to soul⁵². Whether he is insufficiently informed or inadequately prepared to grasp the significance

⁴³ II 6, 743 b 36ff. 744 a 5-14; but see also *De part. an.* II 7, 652 b 3ff.

⁴⁴ See above pp. 169ff. 173 n. 23. 176 for some of the reasons (and traditions) which determined Aristotle's preference for the heart as seat of the central and coordinating organ. The physiological arguments were weighty, and so were the speculative ones.

⁴⁵ This is a rough estimate. All that we can honestly say about the time of Herophilus' discoveries is that they fall within the former half of the third century.

⁴⁶ Erasistratus is quoted for the remark *οὐδὲν ὀρθῶς ἐγνωκέναι περὶ φύσεως τοῦ Περιπατητικοῦ* (Gal. *In Hipp. de alim.* III 14; XV 307 K.).

⁴⁷ See above p. 183.

⁴⁸ 5, 483 b 15; cf. Wellmann, RE s.v. *Erasistratus* 337; Jaeger, loc. cit. 64.

⁴⁹ 6, 484 a 17; 7, 484 b 35ff.; 8, 485 a 6f.; note however the discrepancy between the last passage and 5, 483 b 12f. Cf. Jaeger 70.

⁵⁰ Above p. 183.

⁵¹ 7, 484 b 20f. It is possible that what he here has in mind is the views set forth in the *Timaeus*. To an outsider, Herophilus' theories might look like a revival of these views.

⁵² See esp. 5, 483 a 30-35 where various possible relations between *ψυχή* and *πνεῦμα* are pondered. The subject of *νοῦς* or *διάνοια* is never brought up in the treatise; nor are the sense organs and their relation to a central organ discussed.

of the new developments, our conclusion must in either case be the same. As Jaeger has said, the lead in the progress of scientific investigation has passed from the Peripatus to the researchers of Alexandria⁵³.

In the Stoic school the implications of Herophilus' and Erasistratus' discoveries were equally unwelcome. Yet on the part of Cleanthes no reaction is known and it appears that the task of taking up the cudgels devolved on Chrysippus. With his characteristic honesty he frankly confessed himself unfamiliar with anatomy and ignorant regarding the origin of the nerves⁵⁴. But the *hegemonikon* had to remain in the heart. The best that Chrysippus could do in the matter was to fall back on the authority of Praxagoras⁵⁵. Washing his hands of the specific physiological issues⁵⁶, Chrysippus turned to criteria of a different type. Common sense, general or popular opinion, views set forth by the poets or to be elicited from them by the methods of Stoic interpretation, etymologies, and of course also aprioristic arguments could be marshalled against the conclusions emerging from the anatomical investigations⁵⁷. Stoic physics and physiology had ever since their beginning made large borrowings from the prevailing physiological theory yet the ties between the dogma of the school and medical research had probably never been very close. The Stoics had developed the *πνεῦμα* doctrine along their own line. Chrysippus' dogged defense of the school dogma regarding the seat of *hegemonikon* inevitably widened the gulf between philosophy and science. Praxagoras had probably worked out his system before 280 or at the latest before 270. Chrysippus became head of the Stoic school in 232. It is a measure of his predicament that he had to go back roughly 50 years to find his scientific authority. His feeling for scientific progress may not have been very vivid.

The third and last reaction to be mentioned is as far as it goes more appreciative; however it is altogether of a 'lighter' kind and has no bearing on either the future of Greek thought or the decisions about weighty intellectual issues. When Apollonius describes the agonies of Medea's love—agonies which keep her awake at night while everything else is enveloped in an atmosphere of quiet—he places the onrush of emotions in her heart (*κραδίῃ*). This, it is hardly necessary to say, corresponds to the conventions and traditions of poetry. But no convention and no precedent guided Apollonius when immediately after mentioning Medea's tears he continues:

ἐνδοθι δ' αἰεὶ
τεῖρ' ὀδύνη σμύχουσα διὰ χροός, ἀμφί τ' ἀραιάς
ἵνας καὶ κεφαλῆς ὑπὸ νείατον ἰνίον ἄχρως
ἐνθ' ἀλεγεινότατον δύνει ἄχος ὁππότε' ἀνίας
ἀκάματοι πραπίδεςσιν ἐνισκίμπωσιν "Ἐρωτες"⁵⁸.

⁵³ Loc. cit. 69f.

⁵⁴ St. V.F. II 897.

⁵⁵ Ibid. (246, 24 v. A.) Χρύσιππος ἀντιθεῖς (scil. Πραξαγόραν) τοῖς ἀπὸ τῆς κεφαλῆς ἀρχεσθαι τὰ νεῦρα νομίζουσιν.

⁵⁶ Ibid.; see also II 885 (note 239, 17ff. v. A. for the organization of Chrysippus' treatise).

⁵⁷ Ibid. II 883. 886ff. 901ff. 911 and pass.

⁵⁸ Apoll. Rhod. III 761–765.

Although at the end of this passage Apollonius finds his way back to the conventional poetic physiology, he has clearly departed from it where he speaks of the fine or thin *ἵνες* and of the lowest part of the occiput (*ὀπίον*). In the Homeric language *ἵνες* denotes the fibres. But Apollonius is not bound by Homeric usage⁵⁹. The *ἵνες* which here carry the physical pain to the lower end of the occiput must be the nerves. Some interpreters of Apollonius have in fact accepted the word here in this meaning—without realizing that it is an unusual meaning and that it has a special point⁶⁰. Apollonius could have used the Homeric *νεῦρον* but it was much more ingenious to exploit the similarity of *ἵνες* and *ὀπίον*—in the poetic medium this could almost pass as a linguistic proof for the correctness of the exciting new discoveries^{60a}. This is not the only instance in which an Alexandrian poet shows himself abreast with contemporary developments in the sphere of scientific research⁶¹. The Hellenistic *poeta doctus* knows how to incorporate the modern and the up-to-date in his supposedly tradition-bound form.

It will hardly be wise to try to extract from these verses some 'factual' gain for the subject of our paper. We might wish to ask: Did Herophilus or Erasistratus think of the nerves as carriers not only of sense perceptions and of *προαίσεις* but also of emotions? Had the seat of pain (and of its inevitable partner in life and physiological theory, pleasure) been transferred from the heart to the brain^{61a}? Does *ὀπίον* allude to a localization of the nerve-endings in the cerebellum? Poetry is too elusive to satisfy our technical curiosity; nor should we forget that the poet here plays with words and that not only *doctrina* but also an element of 'experience'⁶² may be incorporated in his verses.

For later poets of love Apollonius' detailed and penetrating description of its symptoms was a storehouse of motifs; even the Fourth Aeneid is in his debt⁶³.

⁵⁹ The last treatment of this subject is Hartmut Erbse's in *Hermes* 81 (1953) 163ff. (Apollonius' knowledge of medical literature and medical terms *ibid.* 186ff.; our passage appraised in general terms and so far correctly 189f.).

⁶⁰ Cf. G. W. Mooney, *The Argon. of Apoll.* (London 1912) *ad loc.* who also quotes a correct translation of the passage by A. S. Way.

^{60a} Curiously, *νεῦρα* spreading out from the occiput (*ὀπίον*) are described in "Hipp." *De nat. oss.* 3 ("des nerfs, c'est-à-dire des parties blanches, tendineuses, membraneuses", Littré *ad loc.* IX 171).

⁶¹ The closest parallel is to be found in Callim. *Hymn. in Dian.* 53 where H. Oppermann (*Hermes* 60 [1925] 14ff.) detected an allusion to the four tunics of the eye, one of the important discoveries made by Herophilus in the course of his anatomical work. On the other hand, Eratosthenes frg. 25 Powell which speaks of drink as moistening the lungs probably reflects his Platonism rather than his interest in the science of his day.

^{61a} This inference is almost irresistible. If it is correct, the new insight must have been startling. For the conviction that pleasure and pain are felt in the heart had been particularly persistent and is again and again used as a trump card in the arguments for the heart as the central organ (see "Hipp." *De morbo sacro* 17; Arist. *De part. an.* III 4, 661 a 11; Epicurus in Lucr. III 141f.; Chrys. *St. V.F.* II 899f.).

⁶² One may suspect that once the discoveries had become known not a few people persuaded themselves that they "felt" the pain where the new theories—rightly or wrongly understood—taught that it was reported.

⁶³ See the commentators on Book IV. Even R. G. Austin (London 1955) who reacts against the fashion of stressing Vergil's models mentions Apoll. III 744 in connection with *Aen.* IV 522ff.

But the pain affecting the nerves is not among the symptoms often or readily borrowed. Poetic taste seems to have balked at the idea of resorting to so physical—not to say clinical—a feature of the erotic agony⁶⁴. Apollonius had the excuse of 'novelty'. Moreover, being tactful enough to disguise, rather than to emphasize, the scientific novelty he succeeded in incorporating it in his epic without producing a jarring note.

In questions relating to physiological doctrine I have profited from the helpful advice of Konrad Akert and Margaret Orsini. I am also indebted to Marshall Clagett and Julius Weinberg for giving me important references. The Institute for Research in the Humanities at the University of Wisconsin by appointing me as Visiting Professor for 1960–61 enabled me to complete this study.

⁶⁴ Mooney (see note 60) *ad loc.* cannot conceal his disgust at the "physical particularity". By 1912 "specificity" had not yet become a literary creed.