

THE PARADOXICAL TEXT 'ON THE HEART'

PART II

by

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ἔν τῇ αἰσθήσει ἡ κρίσις—Aristotle*

ERASISTRATUS AND THE VALVES

Erasistratus described all four valves, 'On the Heart' describes only two. Is 'On the Heart' using the discovery which Galen emphatically attributes to Erasistratus, and to no-one else, but using it only in part? This question prompts a further one: what was the real nature of Erasistratus' discovery?

References to Erasistratus on the valves are scattered throughout the corpus of Galen's works, and Galen, it is salutary to remember, was not writing history but defining his own views and defending them against rival views. Polemic is of the essence of Galen's mode of exposition, and in this he was a true Greek. We may at times suspect his accuracy, and in any case the removal, intact and undistorted, of a particular doctrine from among the complicated tissues of Galenic controversy is an operation which requires some care. Thus the locus classicus on Erasistratus' discovery of the valves occurs in *de Placitis* 6.6 (V, 549K), and the context of this passage is Galen's development and defence of his own view that not the heart, as Aristotle and Erasistratus said, but the liver is the ARCHĒ or starting point of the veins. The context is further complicated by the fact that Galen opposes his own view not only to that of Aristotle and Erasistratus but to that of certain followers of Erasistratus who appear to have 'developed' Erasistratus' views on the function of the liver in line with Aristotelian doctrine. This view, according to Galen, assumes a flow of material from the right heart down the vena cava. But this, he says, contradicts the celebrated discovery of their own master Erasistratus, for the tricuspid valve on (as both Erasistratus and Galen regarded it) the vena cava prevents any backward flow of material from the right heart into the vena cava. Thus from Galen's point of view it is the atrio-ventricular valves which are important, and more particularly the right atrio-ventricular valve; and it is the function of these that he stresses. In view of the passage cited earlier, where Galen seems to say that it was these, atrio-ventricular, valves that Herophilus described 'carelessly', and Erasistratus 'precisely', we might be disposed to argue that it was these valves which it was Erasistratus' peculiar glory to have discovered, rather than the semilunar valves. In another passage too Galen seems to stress the atrio-ventricular valves (*Nat. Fac.* 2, 1, II, 77K): 'not even Erasistratus wishes any other part [sc. than the lung] to be nourished from the heart, because of the implantation of the membranes (DIA TĒN TŌN HUMENŌN EPIPHUSIN, i.e. the tricuspid valve which prevents any backward flow into the vena cava).'

Such a possibility³⁴ should not be immediately rejected: it may be a means of discerning the true arrangement of the historical facts, if any confirmatory evidence can

* The Editor regrets the typographical errors in this quotation in Part I.

³⁴ It was canvassed by Wellmann, *Fragmente der Sizelischen Ärzten*, p. 106.

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be found. Nevertheless, in the passage from the *De Placitis* Galen, despite the fact that his main interest is in the atrio-ventricular valves, does give full measure to Erasistratus' description of the other two as well. We had better look at the whole passage, a golden fragment among the miserable ruins of Alexandrian medicine.

The phenomenon is described by Erasistratus in his work 'On Fevers', how membranes adhere to the orifices of the vessels which the heart employs in the service of introducing and expelling its material. Some have had the effrontery to deny the existence of these membranes, saying that Erasistratus invented them for the sake of establishing his doctrine.³⁵ But knowledge of them is by now so general among physicians, that anyone who did not know about them would be regarded as antediluvian. There are upon the orifice of the vena cava three membranes which are very similar in their arrangement to cusps—which I suppose is why some followers of Erasistratus gave them the name 'tricuspid'. But on the venous artery (as I call the branching vessel which goes from the left cavity of the heart into the lung) the membranes, while very similar in shape, are unequal in number. For to this orifice alone, only two membranes adhere. Of the other two orifices, each has three membranes, all of them sigmoid (i.e. semilunar). Now as Erasistratus says in explaining the phenomenon, of the two orifices one expels blood into the lung, the other, pneuma into the whole living creature. These membranes, as he thinks, perform a reciprocal service to the heart, by alternating at the appropriate times—those which adhere to the vessels which introduce material being carried in an inward direction, and tripped up by the entering material, falling back into the cavities of the heart and, by opening their orifices, giving an unimpeded passage to what the heart draws in. For, he says, material does not rush in of its own impetus, as it might into some lifeless cistern, but it is the heart itself which by dilating, like the blacksmith's bellows, draws in material and fills itself in diastole. But those membranes which, we said, lie on the vessels which expel material, are considered by Erasistratus to behave in the opposite way. For they incline from within in an outwards direction, being tripped by the material passing out, and so opening the orifices at the time when the heart distributes its material. But at every other time the orifices are tightly closed, forbidding any material which has been emitted to return. In the same way (he says that) the membranes upon the vessels which introduce material, close the orifices when the heart contracts, not allowing what the heart has attracted to escape back again. (*De Placitis* 6.6, V, 548–550K).

Erasistratus had been a pupil of the peripatetic philosopher Strato of Lampsacus, a hard-headed mechanist who stripped the Aristotelian nature of her divine attributes and left her as a mechanical force operating 'by weights and movements'.³⁶ In her reduced state, she looks something like the ANANKĒ or mechanical necessity of the atomists, but unlike ANANKĒ, Stratonian nature has a purpose, and Strato was a teleologist. But the similarity to Democritus serves to remind us of a mechanical strain in earlier Greek medicine, in particular as it appears in the author of the treatises 'On Generation', 'On the Nature of the Child' and 'On Diseases 4'.³⁷ This author loves to construct models, such as the model in ch. 39 of three vessels connected at their bases with pipes so that, as fluid is poured into one vessel, the level in the others rises. This particular model represents the relation between the four main organs or reservoirs in the body which intercommunicate the humours. It is not a mere decorative tour de force, for it is evident that the author finds a real help, both in his embryology and his physiology, in such a mechanical way of visualizing processes. It is a demonstration model, to make the process clearer to the reader, but it also has a certain

³⁵ As Abel (op. cit., p. 82) points out, this remark of Galen's, if true, shows that the valves were not generally known, if known at all, before Erasistratus—otherwise the slander has no point.

³⁶ Cicero, *Academica* II, 38, 121 = Fr. 32 Wehrli.

³⁷ Littré, Vol. VII, pp. 470ff. and, recently edited with French translation by R. Joly, in the Budé series. A text, translation, and commentary is being prepared by G. Baader and I. M. Lonie for the series 'Ars Medica'. On the content of the treatises see especially O. Regenbogen, *Quell. Stud. Ges. Math.*, 1929/30, 1, 131–82 and G. E. R. Lloyd, *Polarity and Analogy* passim.

heuristic value for the author himself. The same is true of the model he uses to illustrate the process of articulation in the embryo: 'Suppose you were to tie a bladder on to the end of a pipe, and insert through the pipe earth, sand, and fine filings of lead. Now pour in water, and blow through the pipe. First of all the ingredients will be thoroughly mixed up with the water, but after you have blown for a time, the lead will move towards the lead, the sand towards the sand, and the earth towards the earth. Now allow the ingredients to dry out and examine them by cutting around the bladder: you will find that like ingredients have gone to join like. Now the seed or rather the flesh is separated into members by precisely the same process, with like going to join like'.³⁸

But there is one feature which these two models, and the others used by the author, have in common, a feature worth considering for it gives us an insight into the development of ancient science. The apparatuses whose construction the author describes are not *useful* pieces of apparatus. They are gratuitous, ad hoc, serving no purpose independent of the author's own. The author thinks in terms of mechanistic processes but he does not, if the distinction is allowed, think in terms of machines—of apparatus simple or intricate, with each part in a logical relation to every other part, and all arranged in a logical hierarchy of which the particular purpose of the machine is at the summit. There is evidently mechanism and mechanism in Greek science—of mechanical process on the one hand and functional machine on the other.

Erasistratus' conception of the heart is of the latter kind: it is that of a functional machine, in which part and function cannot be separated from each other and considered in isolation.³⁹ The four valves, the two kinds of material (blood and pneuma) are so to speak enfolded and included in the action of the heart: it is a unitary conception.

Erasistratus himself, to judge from the passage in Galen, compared the action of the heart to that of the blacksmith's bellows, which was no doubt the most familiar form of pumping device in the ancient world.⁴⁰ But the heart as Erasistratus conceived it is in fact a two-stroke (i.e. combined suction- and force-) pump with double action (since it is designed to move two different fluids, blood and pneuma, simultaneously).

A pump, with two alternating sets of valves, is described by Philo of Byzantium (third or second century B.C.).⁴¹ It is a simple fire-engine pump, or the kind that used to be employed for pumping ships. In order to keep up a constant jet of water the pump has two cylinders whose intake and output alternate.

The similarity between this pump and Erasistratus' heart is that each has two sets of valves. Otherwise the differences are considerable: the heart is not a piston pump,

³⁸ *De Natura Pueri* ch. 17 (VII, p. 498 Littré). For the explanation of this model, in its relation to what it is meant to illustrate, and in its Democritean affiliations, see C. Müller, *Gleiches zum Gleichen*, Wiesbaden 1965, 115–22.

³⁹ Cf. the remarks of L. G. Wilson, op. cit. (n. 31), p. 297.

⁴⁰ The same comparison is applied to the auricles in 'On the Heart', ch. 8. It seems to be a quite common comparison: we find it in Aristotle, *De Respiratione*, 480A20, and several times in Galen (e.g. VIII, 703K; III, 483K). It may have been used by the Pneumatic School: Kudlien, op. cit., p. 427, notes its occurrence in Gregory of Nyssa, *De Opificio Hominis*, Migne, *Patres Graeci* XLIV, col. 245, where it is applied to the heart—a passage perhaps influenced by Posidonius.

⁴¹ The description is most easily accessible in Hero of Alexandria, *Pneumatics* I, 28, translated in W. R. Cohen and J. E. Drabkin, *A Source Book in Greek Science*, 1948, pp. 329–31, with two illustrations. Cf. also Singer, Holmyard etc., *A History of Technology*, II, p. 634, and for a discussion see A. G. Drachmann, *The Mechanical Technology of Greek and Roman Antiquity*, 1963, pp. 155–57.

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and collapsible bellows are a better analogy to its action of diastole and systole. Moreover the pump described in Hero alternates—this indeed is its TELOS—in order to keep up a constant jet of water, whereas the heart of course sends out its material in pulses. Thirdly, the pump moves one material only, water, whereas the heart moves two, blood and pneuma. The differences are perhaps greater than the similarities. Yet both are the index of a particular way of thinking—of seeing things in terms of a definite series of events, designed to achieve a particular end. The pump in Hero, and Erasistratus' four-valved heart, recognizably come from the same world—and from the same period.⁴² The heart in Erasistratus is conceived as a machine: it is mechanistic, in the second of the two senses suggested above.

From this point of view, it hardly matters whether Erasistratus discovered the semilunar valves as well as the atrio-ventricular valves (which as valves he certainly did discover), or whether they were known before him. If they were known before him, he 'rediscovered' them, in the sense that he brought them into his unitary conception of the action of the heart, and showed that they, along with the atrio-ventriculans, have an essential and equal role in that action. Their function cannot be considered in isolation. It is thus after all the idea of *action* that is predominant in Erasistratus' picture of the heart, while anatomical structure is subordinate to this idea. But the idea of action is simply Aristotle's ENERGEIA—and it is moving to see how, in Erasistratus, conception of the heart, those two strains of mechanism and teleology which Plato in the Laws (X, 889Aff.) so sharply and inimically opposed, are united at last in marriage, under the fairest auspices.

It was this anatomico-physiological conception that was the real nature of Erasistratus' discovery—the question I posed at the beginning of this section. Some or all of its elements, anatomical and physiological, may have existed before him, although probably not, as we have seen, the recognition of the atrio-ventricular valves as valves.⁴³ But once this discovery, in this sense, had been made, was it reversible? It could certainly be rejected outright—and as we have seen, some of Erasistratus' contemporaries did so,⁴⁴ as did Asclepiades later on.⁴⁵ But could it be retained in part, and rejected in part? It seems unlikely: not only would such a partial acceptance make nonsense of Erasistratus' unitary conception, but it would involve the loss of a splendid opportunity for teleological moralizing—such as that in which the author of 'On the Heart' indulges. We must nevertheless entertain the possibility—for it is a curious fact that neither the Stoics nor the Stoic-influenced Pneumatic school nor the Church Fathers who echo the Stoic theme *de fabrica hominis* ever specifically mention the

⁴² Erasistratus might well have seen this pump, since it was originally invented by the practical genius Ctesibius, who probably lived in Alexandria in the reign of Ptolemy II (283–247) and was therefore a contemporary and fellow-citizen of Erasistratus. For the relations between Hero, Philo, and Ctesibius see now H. B. Gottschalk, *Strato of Lampsacus: Some Texts* (Proc. Leeds Philosophical and Literary Society, Literary and Historical Section, Vol. XI, 1965, pp. 95–82), pp. 133ff.; and A. G. Drachmann, *Ktesibios, Philon and Heron*, Acta Historica scientiarum naturalium et medicinae, Vol. 4, Copenhagen, 1948.

For a similar problem in connexion with William Harvey, see Walter Pagel, *op. cit.*, pp. 212–13 and n. 14, especially with reference to C. Webster in *Bull. Hist. Med.*, 1965, 39, pp. 508–17.

⁴³ It is significant in this respect that they were first named, not by Erasistratus himself but by his successors.

⁴⁴ Cf. Galen V, 548K., quoted above.

⁴⁵ Galen I, 109K.

valves. Yet they were not averse from such detail: the function of the epiglottis features prominently in Cicero's rhetorical treatment of the theme.⁴⁶ Yet it is also probable that the Stoics and Pneumatics 'knew' of, or rather accepted, the valves and their function. For Galen, who says that most physicians of his time took them for granted, would certainly have mentioned the Pneumatic school, if they had been an exception; and acceptance by the Stoics can I think be inferred from Cicero, *De Natura Deorum* 2.138 with Gregory of Nyssa, *De Opificio Hominis* ch. 30, *Patres Graeci* XLIV, col. 240ff. Migne.⁴⁷ Cicero says: 'nam quae spiritu in pulmones anima ducitur, ea calescit primum ipso ab spiritu, deinde contagione pulmonum, ex eaque pars redditur respirando, pars concipitur cordis parte quadam, quem ventriculum cordis appellant, cui similis alter adiunctus est, in quem sanguis a iecore per venam illam cavam influit; eoque modo ex his partibus et sanguis per venas in omne corpus diffunditur et spiritus per artus.' And Gregory of Nyssa: 'The heart is contained in the middle of the lung, and in perpetual motion, in which it imitates the action of fire, which moves eternally, it attracts, like bellows in foundries, material from the lung placed alongside it, filling its own cavities as it dilates, and fanning what is fiery in itself, it breathes it out into the adjoining arteries. And it never ceases from doing this: in dilation, attracting from outside into its cavities, and in compression, distributing material from itself into the arteries' (op. cit. col. 245C).

What is significant in both passages if they are combined is the movement of diastole and systole (implied in Cicero, and mentioned explicitly in Gregory), by which blood on the one hand, and pneuma on the other, is alternately attracted into the heart and distributed from the heart to the body. This could hardly be visualized without the assumption of valves—which are in any case implicit in the comparison of the heart's action to that of bellows.

The lack of any specific mention of the valves in later sources is odd, but we cannot assume that they were discarded, either wholly or in part, except by Asclepiades and the Methodists. Indeed the evidence, such as it is, points rather in the opposite direction. We may assume that Erasistratus' 'discovery', in the sense defined above, remained unreversed.

The conception of 'On the Heart', where there are only two valves, and no 'action' of diastole and systole, is quite different from that of Erasistratus. But it must be admitted that the details of its physiology are quite indistinct and uncertain. Although there is no account such as Erasistratus gave of diastole and systole, the author does speak of the heart as 'leaping' (chapters 1 and 8), and gives a striking observation of the difference in movement between the 'ears' and the heart as a whole: 'you can see the heart jumping as a whole, while the ears inflate and collapse with a movement of their own' (ch. 8). Significant too is the description of the heart as 'a very strong muscle' (ch. 4). What the function of its musculature is we are not told. Evidently it has nothing to do with the passage of air between the heart and the lungs, in which the author is primarily interested, for it is the 'ears' which 'handle' (KHEIROUTAI) the

⁴⁶ *De Natura Deorum* 2.163: probably from Posidonius, who was interested in the epiglottis from this point of view: cf. Scholiast on Homer, II.22.325 and Reinhardt, RE XXII, 1, 708ff.

⁴⁷ It is Kudlien, op. cit., p. 426, who makes the suggestion that Gregory may be used to clarify points left obscure by Cicero, on the hypothesis that both are directly or indirectly making use of Posidonius. I think this hypothesis is well grounded.

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breathing from the lung into the heart (ch. 8). But the question of the heart's musculature and its function involves a cluster of problems.

According to the interpretation of the anatomy in ch. 7 given previously, the 'ears' whose partial removal exposes the four orifices must include the atria as well as the auricles proper. Hence the author can describe them as 'cavernous' (SÉRANGÔDEA) and can compare them to the blacksmith's bellows. The right atrium is also regarded as the terminal section of the vena cava, and presumably, by an obvious analogy, the left atrium of the pulmonary veins.

This was the view shared by Galen with Erasistratus, whose view of the relation between the auricles and the heart was contrary to that of Herophilus: 'If anyone, like Herophilus, regards [the auricles] as part of the heart, he has increased the number of the orifices, and in this he will appear to be at variance with Erasistratus and myself, who have said that there are four orifices in all' (Galen II 624K; cf. Wellmann *RE* s.v. Erasistratus 340, 68). The number of orifices would be increased because the vena cava would then be regarded as having two orifices, with four for the pulmonary veins, which Galen regards as one.⁴⁸ This supposition is part of the standard, 'classical', picture of the heart with its two chambers and four orifices (there is, says Galen *de Placitis* 6.6 (V, 551K) no 'fifth opening'), which can thus be brought back to Erasistratus—and is found in 'On the Heart'.

In the *De Usu Partium* 6.15 (III, 481 K) Galen has something to say of the function of the atria regarded as part of the vessels: 'It seems to me that when the heart exerts its full powers of attraction, it would actually tear a vessel to pieces if our Creator had not in this instance too contrived a protection against such an accident by placing outside each opening that admits material another separate cavity like a storehouse for nutriment, so that the vessel may not be in danger of rupturing when at times the heart attracts suddenly and violently and the vessel alone, because it is so narrow, cannot furnish abundantly all that the heart demands . . . Thus the auricles of the heart were not formed in vain, though no good sense was used in naming them . . .' (trans. May, pp. 316–17).

We have of course no reason to suppose that this was also Erasistratus' explanation, although it would be quite in accordance with his views. But it does help to bring into focus a problem both in the text of 'On the Heart' ch. 8, and in the physiology of the treatise. The received text reads '(the craftsman) seeing that the organ would be a solid thing, owing to the density [?] of its material [text uncertain], and in consequence entirely attractive, equipped it with bellows, as blacksmiths do their furnaces, by means of which to control [or 'manage'] its respiration'. Unger changed the reading, by supplying a negative, to 'and in consequence not at all attractive'. His reason for doing so is in the following chapter, where it is what is 'soft' or 'yielding' (MALAKON), not what is hard or solid, that has the greater attractive power—this is the reason, says the author, why the left heart breathes through veins, instead of through an artery like the right heart. Unger's change has much to recommend it. Without it, there is a contradiction between the two chapters, and the transitional phrase at the

⁴⁸ Cf. *De Usu Partium* 6.7 (III, 436K) and May, p. 292, n. 28; *de Placitis* 6.6 (V, 548), where Erasistratus is represented as speaking of the (one) orifice of the (one) vena cava; *De Usu Partium* 6.20 (III, 507K), where Galen speaks of the *foramen ovale* in the embryonic heart as 'opening the [pulmonary artery] into the great artery and the [pulmonary vein] into the vena cava'.

beginning of ch. 9, 'for this reason' (DIA TOUTO), loses its significance. Yet Galen's 'powerfully attractive heart', to whose force the atria serve as moderators, does tempt us to leave the text as it stands, with a query against it. The purpose of the auricles in 'On the Heart' would then be to control the draught rather than to create it; and to describe the heart as 'entirely attractive' would give some purpose to its powerful musculature, which at present it lacks. What does the heart do with its muscles? It provides blood for the lung, we are told, and this is presumably by pumping—but does it attract blood, or at least potentially sanguineous material, from the vena cava? And does it, from the left ventricle, send out that luminous substance to the rest of the body? Presumably it does, since it is equipped with a unidirectional valve on the aorta. We begin to suspect that the author has left half the story untold—which is not the same as saying that he has told all he knows. It is the same situation as we have found several times before: clear and surprisingly sophisticated detail on the one hand, suggesting a well-developed background of anatomy and physiology, and an elusive vagueness on the other—like, perhaps, a badly remembered lesson.

In points of detail there is both agreement and disagreement with Erasistratus. Unlike Erasistratus, he regards the arteries as containing blood, and he situates the intellect in the heart, whereas Erasistratus located it in the membranes of the brain. On the other hand, the reason he gives that the left heart is fed from the lung through veins, because of their greater attractive power, implies the principle 'horror vacui' (PROS TO KENOUMENON AKOLOUTHIA) of which Erasistratus made such systematic use.⁴⁹

The point on which the author of 'On the Heart' most obviously deviates from Erasistratus is his insistence that ingested fluid, or a portion thereof, passes into the lung, a belief which he demonstrates by slaughtering a thirsty pig who has been given dyed water to drink (ch. 2). The view that the trachea is the normal passage, and the lung the normal receptacle, for *all* fluids, was held by Philistion and subsequently to, and perhaps in dependence upon, Philistion, by Plato.⁵⁰ The function of the fluid which reaches the lung in this way is to cool the heat of the heart.

The view that is represented in 'On the Heart' differs significantly from the view stated by Plato. While in Plato *all* the fluid swallowed passes down the trachea into the lungs—the passage in *Timaeus*, 91A leaves no doubt about this—in 'On the Heart' it is only a portion, and that a very small one, which passes down the trachea. The reason given is the 'precise fit' of the epiglottis. Moreover, although the author retains the cooling function of this liquid, it does not cool by remaining in the lungs but by being filtered out and gathering round the heart itself, inside the pericardium, as the pericardial fluid. We cannot then equate *tout court*, as has sometimes been done, the view of 'On the Heart' and of Plato, and regard both as the view of the Sicilian school of medicine.

⁴⁹ There is even perhaps a coincidence in vocabulary: the word DEXAMENE, properly meaning a tank or cistern, is used by the author of 'On the Heart' to refer to the right ventricle. It was evidently used in reference to the heart by Erasistratus, in the passage quoted above from Galen, *De Placitis*: "the heart" says Erasistratus "is no lifeless receptacle (DEXAMENE)". Galen himself may be echoing Erasistratus in another passage, *De Usu Part.* 6. 11 (III, 461K), where he describes the right chamber of the heart as a DEXAMENE. This is a frail point of course; but the word is not particularly common. It was used however by Democritus—of the blood vessels (B135).

⁵⁰ For Philistion, see Plutarch, *Quaest. Conviv.* 7. 1, 699A; for Plato, see *Timaeus* 70C; 91A; and in general F. Kudlien, *Der Beginn des medizinischen Denkens bei den Griechen*, 1967, p. 88ff.

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The view as it appears in Plato was disputed both before and after Plato's time. It was disputed before Plato⁵¹ in *Diseases 4* ch. 56, where the author proudly enumerates seven arguments from observation (HISTORIA) against the view (and then adds another one for luck); and after Plato by Aristotle ('On the Parts of Animals' 3.3, 664B3ff.) and by Erasistratus (whose arguments are recorded in Plutarch op. cit.). Some of the arguments used in *Diseases 4* reappear in a recognizable form, both in Aristotle and in Erasistratus. One of these arguments is the function of the epiglottis, which has evidently not yet acquired its name in *Diseases 4* (nor, in fact, anywhere in the Hippocratic Collection apart from 'On the Heart'), where it is described as '(a covering) like a leaf of ivy', but which is named in Aristotle. Aristotle gives an accurate description of the epiglottis and its function, and as one might expect, it is for him a valuable illustration of the purposiveness of nature (as it was to become for the Stoics: see above).

Now the recognition of the existence and function of the epiglottis was not decisive against Plato's view, or at least a modified version of that view, for it was defended by Dexippus 'the Hippocratic' as Plutarch op. cit. calls him,⁵² who recognized the epiglottis, but reformulated the theory and stated that only a small portion of liquid enters the lung. Dexippus' words as reported by Plutarch have a curious resemblance to those of 'On the Heart'. The function of the epiglottis is 'to filter through the drink gently and in small quantities so that it does not force back and disturb the breath by rushing in in a mass' (Cf. 'On the Heart', ch. 2: 'Since the liquid flows through the crevice in small quantities it does not obstruct the ascent of the air'). It also performs, as in 'On the Heart', the service of moistening the trachea.

It is this reformulated view, depending upon the recognition of the epiglottis, which we have in 'On the Heart', and to it, the author has added the demonstration with the pig, not mentioned in Plutarch. To claim that it is post-Platonic is not to stretch the evidence beyond toleration, for surely Plato (or his source) would not have disregarded the opportunities, exploited by Aristotle and the Stoics, for making a teleological point of the epiglottis. Indeed, according to Plutarch, Erasistratus criticized him sharply for this omission, one altogether inappropriate in a philosopher who 'sought after the final cause of each part of the body'. The formulation given by Dexippus—and used in 'On the Heart'—shows how this might be done without sacrificing the essence of the view that liquids pass into the lung.

Once again, the evidence points to a degree of relatively late development in 'On the Heart'—and once again, it serves to detach the author from any historically identifiable personality or doctrine. For Erasistratus, who knew about the epiglottis, did not himself adopt the modified view of Dexippus—he is rather opposed by Plutarch to Dexippus.

By adopting this modified, and therefore later, view, the author of 'On the Heart' gets, so to speak, two 'final causes' for the price of one. This brings us to the question of—

Teleology.

The most striking single feature of 'On the Heart' is its teleology. Not only are

⁵¹ I ask indulgence for the assumption that '*Diseases 4*' is pre-Platonic or at least pre-*Timaeus*, although I think this will be readily granted.

⁵² The name in Plutarch is Dioxippus: for the identification with Dexippus see Wellmann in *RE* V, 294.

particular details in the anatomy of the heart provided with a functional⁵³ explanation, but the whole structure of the work is designed to lead up to the explanation of the working of the semilunar valves which, as we shall see, the author regards as 'a masterpiece of Nature's craftsmanship'. The treatise, in structure, is a pietistic sermon on such craftsmanship as it is revealed in the workings of the heart. But perhaps more significant than this is the degree to which the author has absorbed a functional approach to anatomy and physiology—the extent to which he takes such functional (and, in the context of Greek science, teleological) explanations for granted. Thus in his discussion of the pulmonary artery and the pulmonary veins he assumes that an observed anatomical difference requires an explanation in terms of function—an assumption which in earlier Greek science is exceedingly rare. Teleological moralizing may be, and often is, a mere rhetorical flourish; but a functional, and teleological approach of the order which we have here is no mere adventitious decoration which might be learned overnight.

In ch. 1. the pericardial fluid exists 'for this purpose, that the heart might leap in safety (TOUTOU HENEKA, HOKŌS . . .)'. This resembles Plato's *Timaeus*, where the fluid-filled lung is both a cushion for the heart to bounce against, and a cooling system for the heart: a further function which the author goes on to apply to the pericardial fluid. The fluid, he says, resembles urine, 'so that you would think the heart was moving in a bladder', and he goes on to describe the heart—it has an odd sound—as 'lapping up' the fluid from the lung and 'urinating it out'.⁵⁴ Thus the Platonic functions are retained, but the anatomy is different. We remember that Aristotle criticized Plato for describing the lung as a cushion (PA 3.6, 669A14ff.: he does not care to mention that Plato also said that it was for cooling the heart). Perhaps the author remembered it too and ascribed this function to the pericardial fluid instead.

The notion of the protection of organs is a common trait in passages of Greek science which have a teleological approach: vide the *Timaeus*.⁵⁵ It occurs again in

⁵³ The explanation of the structure of an organ by reference to its function is not of course the same as a teleological explanation, which is anthropomorphic, explaining such structure by reference to the 'purpose' of some divinity or conscious power. Indeed, a functional explanation is logically quite compatible with a mechanistic approach to nature, and may even be an inevitable consequence of such an approach (cf. what was said above about the two senses of mechanism in Greek science). Nevertheless, it is an accident of the way in which Greek science developed, from Plato through Aristotle and the Stoics to Galen, that such functional approaches are always implicitly, and often explicitly, teleological. In Plato's *Timaeus* for example, while a particular explanation might, considered in isolation, be regarded as simply functional, the whole approach of the dialogue, in which everything in the visible world is a result of the craftsmanship of the DEMIOURGOS or of his ministers, can leave us in no doubt that particular explanations as well as being functional imply an anthropomorphically conceived 'purpose'. What is true of the *Timaeus* is also true of the whole Galenic corpus. It is true of 'On the Heart' as well: the reference to the 'expert craftsman' in chapter 8 implies a similarly teleological approach in passages of functional explanation where such a power is not explicitly mentioned. It was of course theoretically possible, in any Greek writer, for a functional approach to divest itself of the teleological swaddling which was the legacy of Plato. But I am not aware of any case, apart from the rather doubtful one of Strato of Lampsacus, in which this was in fact done. For practical purposes, in the history of Greek science functional explanations are synonymous with teleological explanations.

⁵⁴ See Unger's text and discussion: he retains the DIOUREEI of the manuscripts, which Littré after Schneider changed to DIORROI. The metaphors are rugged—a reason for retaining them. There is, perhaps, an implicit comparison to the embryo cushioned in the amniotic fluid, which was sometimes identified with urine. The strange accumulation of participles with LAPTOUSA are explained by Kudlien op. cit. p. 425 n.1. as glosses, with reference to Hesychius. He is undoubtedly right.

⁵⁵ SOTERIA and BOËTHEIA, 'salvation' and 'succour' are key words here: cf. W. Theiler, *Teleologische Naturbetrachtung*, p. 75. The author uses TIMORIE in ch. 3.

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chapter 6, where the thick or massive construction of the left heart is 'for the purpose of protection against the strength of the hot'. The same observation, and a similar explanation, is applied by Aristotle to the middle of his three chambers, which is presumably the left ventricle.⁵⁶ The care taken by nature that parts should receive neither more nor less cold and heat than is good for them is implicit in what the author says about the lung in ch. 6, which 'keeps in check the intemperance of the hot', and about the pulmonary vascular system in the three culminating chapters of the work. The function of the air is generally described as a 'service' or even 'cure' (THERAPEIA) in ch. 3.

A feature of teleological explanations are 'Technikvergleichen', parts of the body being compared, in respect of form and function together, to familiar instruments or utensils. In 'On the Heart' the gullet is like a funnel (KHŌNOS) (ch. 2), the left chamber is like a 'mortar' (ch. 5, HOLMOS)—or should we say, a crucible?⁵⁷ And the auricles, 'the instruments (ORGANA) with which nature captures the air', are compared to the bellows on blacksmiths' furnaces. Similarly in ch. 10 the *musculi papillares* (evidently) are called TONOI: the word is fairly general, but seems here to mean 'guy-ropes' or 'stays'.⁵⁸

Thus the short treatise is saturated in teleology: almost every chapter shows some sign of this feature. But the culmination is in chapters 10, 11 and 12—the 'unseen'⁵⁹ membranes of the heart, a work of craftsmanship (ERGON) altogether worthy of description (AXIAPĒGĒTOTATON). That 'worthy of description' may make us pause for a moment. We might sense the tones of the rhetorician, elegantly embroidering upon a TOPOS or set theme. We might suspect the genuineness of his interest: is the anatomy of the heart an end in itself, or merely an occasion for rhetorical display? But the detail is against it: the thorough and personal knowledge of the anatomy of the heart. Rhetoricians do not usually care to be so specific—or to dirty their hands. Indeed, it was a reflection on dirtying one's hands in the zoology laboratory that inspired Aristotle to one of his noblest passages (*On the Parts of Animals* 1.5). Thus the rhetorical touch will be of no use to us in locating the work. But we note in AXIAPĒGĒTOTATON a strand which connects the author on the one hand with Aristotle, and on the other with the more Posidonian passages of Cicero and later writers, down to the Church Fathers.

It would be a hazardous proceeding to attempt to date a work by the presence of teleology in it, and still more hazardous to posit several quite distinct varieties of

⁵⁶ But in Aristotle (*PA* 3.4, 665B) the purpose is 'to guard the source of heat'. Possibly the corresponding passage in 'On the Heart' should be translated similarly. Yet 'strength' (ISKHUS) seems to suggest a potentially deleterious force, particularly since the author has just described the corrosive effect of heat on the chambers.

⁵⁷ Littré takes this to refer to the whole heart. But the author is still speaking of the left chamber and does not return to the heart as a whole until the next chapter, which begins with the words 'both (sc. chambers) are rough inside . . .' (So too Diller interprets the passage *op. cit.*, p. 208). Besides, the author is describing the inside rather than the outside shape—the heart 'is hollowed out inside like a mortar in shape'—and a mortar does not have two compartments.

⁵⁸ Used of the torsion straps of siege engines in Philo's *Belopoeica*. Is this an example of a 'mechanistic' approach? Cf. what was said above about Erasistratus' conception of the heart as a machine.

⁵⁹ 'Unseen' is probably not a neutral word: it has overtones of cosmos worship, and strikes a note similar to that of 'secreta naturae' in such writers as Manilius, Pliny the Elder, the author of the 'Aetna', and Seneca.

teleology, and allot them to different schools or persons. A teleological account *de fabrica corporis humani* seems to go back as far as Diogenes of Apollonia [see Theiler, *op. cit.*, p. 6ff.]. Then there is the famous tour de force in the *Timaeus*. Plato may owe it to Philistion or in general the 'Sicilian school', but it seems more likely that his procedure was to adapt medical doctrines and to give them his own expression [see G. E. R. Lloyd, *Plato as a Natural Scientist*, *JHS* 88 (1968) 78–92]. The teleology may quite easily be his own, and apart from the doubtful case of Diocles, we do not know of any member of the 'Sicilian school'—i.e. Philistion—who indulged in such explanations. Nevertheless, a teleological passage at any time in the fourth century would not surprise us. But the detailed and systematic character of the teleology in 'On the Heart' suggests a later rather than an earlier date—quite apart from other considerations.

The author speaks of the auricles as being the work of an 'expert craftsman' (KHEIRONAKTOS AGATHOU) who observes (KATASKEPSAMENOS) and contrives accordingly. This is obviously reminiscent of Plato's craftsman god of the *Timaeus*, the DĒMIOURGOS. Theiler illuminatingly points out a significant difference—the result of a metaphysical development in Plato and in Aristotle—between the two philosophers in this respect. Plato's DĒMIOURGOS becomes, for Aristotle, PHUSIS, nature, who as efficient cause (ARCHĒ KINĒSEŌS) and formal cause (EIDOS) combined, is in the living thing itself [Theiler, *op. cit.*, p. 90ff.]. We find this Aristotelian conception in ch. 8, already referred to: the auricles are 'the instruments with which nature captures the air'—followed immediately by 'the work of an expert craftsman', just as on occasion Aristotle says 'nature contrives' (PHUSIS DĒMIOURGEI *PA* 654B29; cf. Theiler, p. 89). Plato himself, on the other hand, had reservations about the word PHUSIS, and these reservations are expressed in his last work, *The Laws*.⁶⁰

The movement seems to have been towards a more immanent conception of nature, from Aristotle to the Stoics. From this point of view, 'On the Heart' may be anywhere along that line. We should perhaps put the philosopher Strato of Lampsacus in a class of his own, since his conception of nature was remarkable for its absence of any anthropomorphic feature: it is characterized in that way by the Epicurean Velleius in Cicero's dialogue *De Natura Deorum* (1.35 'Strato . . . qui omnem vim divinam in natura sitam esse censet, quae causas gignendi augendi minuendi habeat, sed careat omni et sensu et figura'. = Fr. 33 Wehrli) and made use of by the Academic Cotta in the third book of that dialogue, who no doubt gives us a more accurate impression: 'Naturae ista sunt (sc. the phenomena of cosmic sympathy and harmony) . . . naturae non artificiose ambulantis, ut ait Zeno, . . . sed omnia cientis et agitantis motibus et mutationibus suis' (3.27). These words of Cotta's seem far removed from the craftsman nature, PHUSIS KHEIRŌNAX, of 'On the Heart', which resembles

⁶⁰ Whether such a conception is present in Diocles or not, we cannot be sure. He certainly gave a teleological explanation of the cotyledons in the uterus (Fr. 27), and Soranus, who reports him speaks of 'nature' as acting 'providentially (PRONOËTIKŌS)' in this. And there is also a 'Technikvergleich' in Fr. 26. The sperm adheres to the womb because of the roughness of the latter, just as those who glue together wood or stone rasp the surfaces first. On this see Diller, *RE* XIX, 2, col. 2408. Certainly Diocles was a teleologist—that is clear; there is no reason why he should not have been one of the Aristotelian "variety", if we can so call it; and if he was Aristotle's pupil, it is more than likely. This may be a reason for associating 'On the Heart' with Diocles and his circle.

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rather the Stoic 'natura artificiose ambulans' referred to by Cotta. But Erasistratus, who had been a pupil of Strato, was according to Galen never tired of extolling the 'craftsmanship' and 'providence' of nature—which he too seems to have regarded as an immanent force.⁶¹ So far as the teleology of 'On the Heart' is concerned, it squares with what we are told of the teleology of Erasistratus.

The history of teleological explanation, and in particular the history of the idea of an immanent PHUSIS, are always fascinating subjects. But we should not allow them to take us too far down the centuries. It is a salutary reminder to turn back to the late fifth or early fourth century and read the famous passage in *Epidemics* 6.5, 1 (V, 314 Littré): 'Natures are the physicians of diseases. Nature herself finds out the methods . . . Nature is cultured: of herself, and without taking instruction, she does what is necessary.'⁶² Compare the craftsman of 'On the Heart', who certainly might be said to 'do what is necessary'. The idea is certainly there, ready for the taking, at the end of the fifth century.

THE NOURISHMENT OF THE LEFT HEART

'Its nutriment' says the author of the left chamber, 'is neither the solid food nor the drink which comes from the belly, but a pure and luminous substance which is refined out of the blood. It conveys this nutriment out of the neighbouring blood receptacle by transmitting its rays, deriving it from there as though from the belly and intestines . . .' (ch. 11).

However the rest of the body is fed—the author does not tell us clearly—the left chamber requires a special nutriment. This is as it should be—KATA PHUSIN—for the left chamber is the seat of the hot and of the intellect (GNŌMĒ).⁶³ Hence its greater thickness and, in comparison with the right chamber, its more corroded appearance; hence too its greater need of refrigeration from the lung. What nourishes the left chamber is not blood, but a 'pure and luminous substance' arising from blood. We may call this substance pneuma, that maid of all work in Greek philosophy and science, who appears in so many and such strange disguises.

Pneuma is universally regarded as the product of moisture and heat. For example, the author of 'On the Nature of the Child' expresses this in quite mechanistic terms: any organic substance, he says, which is heated will, provided that it is moist, produce *pneuma*, and he gives as instance leaves, green wood, legumes (ch. 12, VII, p. 486ff. Littré). For Aristotle too pneuma, despite its ultimate mystical significance, is initially a product of mechanical processes (*GA* 2.6, 742A15): given moisture and heat, pneuma follows 'by necessity' (ANANKĒ, a word which indicates the mechanical explanations so characteristic of pre-Socratic philosophy—and deplored by Plato). In Diogenes of Apollonia sperm was 'pneumatic' (Simplicius, in introducing Fr. 6; DK II, p. 62, 12); it was a foam arising from blood. There is nothing surprising about

⁶¹ See my note 33 on p. 441 of *Bull. Hist. Med.*, 1964. I am now convinced that not only the Erasistrateans, but Erasistratus himself, was a teleologist and that, whatever he may have learned from Strato, he 'anthropomorphized' nature.

⁶² For the reading adopted here, see K. Deichgräber, *Die Epidemien und das Corpus Hippocraticum*, p. 52 and n. 3.

⁶³ The GNŌMĒ . . . which rules over the rest of the soul (PSUCHĒS) ch. 10. GNOME = NOUS (intellect) would seem to be an early use. [In Aretaeus the Pneumatic, which is mentioned by Kudlien op. cit. 427, n. 2 (CMG II, p. 22, 26ff. H.), the word seems rather to mean, as is usual at all periods, 'powers of judgement'.] But of course there may be conscious archaism in 'On the Heart'.

the notion of pneuma arising from moisture and heat. The pneuma produced in this way may be 'vital' or 'animal' pneuma (PNEUMA ZŌTIKON), or 'soul pneuma' (PNEUMA PSUCHIKON). This may have been so for Diogenes; probably it was so for Aristotle. At least in one celebrated passage⁶⁴ he speaks of the 'pneumatization' (PNEUMATŌSIS) of blood: the blood so to speak boils up and volatilizes in the heart. In any case it seems a logical deduction from what Aristotle says elsewhere about pneuma and blood, and about the function of pneuma in the living, moving organism (though we should remember also that even the slightest evidence of such a doctrine was bound to be gratifying to later interpreters). 'Pneumatization' seems to have taken place in the middle chamber of Aristotle's three-chambered heart (*de somno et vigilia* 3.458A10ff.); however there is no chamber which contains just *pneuma*, since all three contain blood (*De Partibus Animalium* 667A1ff.). Above all, Diocles of Carystus is interesting in this matter. Diocles, it is well known, located PNEUMA PSYCHIKON in the heart, as opposed to those (Herophilus, Erasistratus, Strato and others) who located it in the brain, or some part of the brain.⁶⁵ From the heart, PNEUMA PSYCHIKON is sent throughout the body, where it gives rise to voluntary movement [Fuchs 20.550]. Diocles may even have located this pneuma more precisely in the left ventricle of the heart, although the possibility depends on an emendation by Diels [Dox. Graec. p. 304, n. 1] since in the manuscripts it is ascribed to Diogenes, not Diocles.

It is likely enough; in any case Diocles referred to 'the psychic pneuma . . . and the blood which is its next door neighbour' [Fuchs 541: TOU TAUTEI SUNOIKOU HAIMATOS]. This is so like 'the nearest blood receptacle' in 'On the Heart', that it would show a mean and grudging spirit in the matter of evidence to refuse to Diocles the belief that the right heart is for blood, and the left for pneuma. Let us show a similar generosity—it will not in the end impoverish us greatly—in the question how the pneuma originates or whence it is nourished. Wellmann, it is well known, included 'On the Heart' in his capacious net and drew it into the ambit of the Sicilian school of medicine, and those influenced by that school. In discussing the question of how Diocles conceived psychic pneuma to be nourished, he used 'On the Heart' itself as one of his pieces of evidence. We cannot of course do that, and once 'On the Heart' is removed, then the only evidence is a passage from Vindicianus 37 (who *may* represent Diocles here) that *bile* is produced from the blood 'per spirationem tenuem quam graece ἀνασπύλασιν vocamus';⁶⁶ and a passage in the *Timaeus* 86E, in which psychic disturbances are caused by an ATMIS or exhalation from bile and phlegm, which mingles with 'the motion of the soul (TĒI TĒS PSUCHĒS PHORAI)'. Thus the connexion is remote and, so far as the fourth century is concerned, (if 'On the Heart' does indeed belong there), 'On the Heart' is the only work where it is stated that psychic pneuma, in the left ventricle, is nourished by an exhalation of blood from the right.⁶⁷ Yet after all, as we have seen, there is nothing odd either in the fifth century or

⁶⁴ *De Respiratione* 479B17 ff.

⁶⁵ R. Fuchs, 'Anecdota Medica Graeca', *Rheinisches Museum*, 1894, 49, p. 540, 541, 543; Tertullian *De Anima* 15; cf. Fragment 14 Wellmann.

⁶⁶ Notice incidentally the presence of bile in the left chamber in *De Corde* ch. 11.

⁶⁷ According to Alexander Polyhistor quoted by Diogenes Laertius VIII, 30 (= Diels-Kranz I, p. 450, 20) the Pythagoreans believed that the soul is nourished from blood. But Alexander wrote in the first century B.C., and cannot be regarded as a reliable witness for early Pythagorean thought. See A. J. Festugière, *Rev. Études grec.*, 1945, 58, 1 ff. Festugière thinks (p. 49ff.) that Alexander owes his doctrines on pneuma to Diocles.

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the fourth about the idea that pneuma is exhaled from blood; it is also quite possible that Diocles regarded the relation between the left and right chambers as being that which is expressed in 'On the Heart'; and we may reasonably ask rhetorically whence is psychic pneuma in Diocles (or Philistion for that matter) nourished, if not from the blood?

So far the evidence: an unsatisfactory witness, but deserving of the benefit of the doubt. We may leave Diocles for the moment, and turn to another direction: once again it is a matter of style. The left chamber, says the author, derives or rather 'pastures upon' (NEMESTHAI) the blood by 'transmitting its rays or beams' (AKTĪNAS). AKTIS means a ray or beam from any bright object, fire, or lightning or the eye, but it is above all associated with the radiance of the sun. 'O gloriously radiant sun' (AKTIS ĀELIOU) are the words with which the chorus of Thebans in the 'Antigone' greet the dawn after a night of doubt and destruction. It is a potentially reverberant word. The heat in the left chamber of the heart is like the heat and radiance of the sun; the dispenser of life to the microcosm, as the sun is to the macrocosm, but, like the sun, itself requiring nourishment. That the sun, indeed all the heavenly bodies, feeds upon 'exhalations' (ANATHUMIASEIS) is an idea which is at least as old as Heraclitus. Heraclitus may have said, and probably did say that the soul is fed in the same way, although we must be wary of the fragment and testimonium (DK 22A15 and B12) which suggest this, since the fragment itself says nothing of the soul, but is quoted with that interpretation by the Stoic Cleanthes.⁶⁸ The adaptation by the Stoics of Heraclitus to their own doctrines is a familiar phenomenon.

But of the Stoics themselves we can be certain. Although we may suspect that for Diocles psychic pneuma was nourished by an exhalation from blood, we know beyond doubt that among the Stoics this was settled dogma. For Chrysippus, psychic pneuma or, more simply, the soul 'is connate pneuma (PNEUMA SUMPHUTON) extending through the whole body' (Galen, *de Placitis* 3.1, V, 287K = Stoicorum Veterum Fragmenta II, 885). This pneuma is nourished from blood: 'Cleanthes and Chrysippus and Zeno [said] that the soul is nourished from blood, while in its substance it is pneuma' (Galen, *de Placitis* 2.8, V, 283 K = SVF III, 30;⁶⁹ cf. *de Usu Partium* 6.17, III 496K = SVF II, 781, and *de Usu Resp.* IV, 502K = SVF II, 783, where Galen ascribes the view to 'many considerable physicians and philosophers'). The manner of this nourishment is described as 'exhalation' (ANATHUMIASIS): e.g. 'He [sc. Diogenes of Babylon] says that what moves the body in voluntary movements is a psychic exhalation (PSUCHIKĒ ANATHUMIASIS), and all exhalation is derived from nutriment' (Galen, *De Placitis* 2.8 = SVF III, 30); for soul as an ANATHUMIASIS see in general von Armin's index s.v. ψυχῆ. These are clear and unambiguous statements. Where and how the exhalation occurs we are not directly told; it must be, however, from the right ventricle to the left, since for the Stoics blood is created in the liver and sent up the vena cava to the right ventricle.

Now the analogy between the nourishment of the sun from exhalations arising from the earth and ocean, and the nourishment of psychic pneuma by exhalation from the blood—between macrocosm and microcosm—is explicitly associated with Cleanthes

⁶⁸ J. von Arnim, *Stoicorum Veterum Fragmenta* II, 519.

⁶⁹ Cleanthes is put first, suggesting that what is in question here is an interpretation by Cleanthes of his predecessors.

(331–232 B.C.) alone among the Stoics. That man is a microcosm is part of the essence of Stoic philosophy at all periods. But Cleanthes is peculiar in the pre-eminence which he gave, in the macrocosm, to the sun. For Cleanthes the sun is the HĒGEMONIKON, or ruling principle, of the cosmos.⁷⁰ To a Stoic this would mean that the sun in the cosmos corresponds to that part of man to which the term HĒGEMONIKON is properly applied—and this, for all orthodox Stoics, is situated in the heart. Cicero records Cleanthes' own words for us:⁷¹ 'Since then', he says, 'the sun is of fire and is fed by the moisture of the Ocean (for no fire can continue without some fuel), it must resemble either that form of fire which we use for the purposes of daily life or that which is contained by the bodies of animate things. But our fire . . . is a destroyer . . . while that fire which is contained in the body is vital, salutary, preserves, feeds, increases, sustains, and bestows, the power of sensation (*sensuque adficit*)'. He says therefore there can be no doubt which of these kinds of fire the sun resembles, for the sun too makes all things to flourish and grow to maturity each after its kind. Since then the fire of the sun resembles those fires which exist in the bodies of living things . . .'. The heat of the sun and animal heat are for Cleanthes of the same kind: in other words, the sun is the heart of the cosmos, and the heart is the sun of that cosmos which is man. What both have in common is the manner in which they are nourished; and Cleanthes seems to have taken a particular interest in this question, both in the case of the sun, and in the case of the soul. It was by the sun's search for nutriment that Cleanthes explained its 'turnings', or movement along the ecliptic.⁷² In the same way he gave his attention to the meaning of his master Zeno in calling the soul a 'sensible exhalation' (AISTHĒTIKĒ ANATHUMIASIS), and explained it, we are told, by adducing the beliefs of other philosophers, including Heraclitus, as we have seen. Hence, for later writers, Cleanthes was associated with Zeno on the doctrine of the nourishment of the soul by exhalation: as often happens when one Stoic gives an exegesis of a predecessor, the two are thereafter quoted together (cf. SVF I, 520).

The adjective HĒGEMONIKOS is familiar to the author of 'On the Heart'. The aorta, he says, is shut off from the left heart because it is full of 'nutriment not appropriate for the leader' (TROPHĒ OUKH HĒGEMONIKĒ). One is tempted to translate 'unsuitable for the HĒGEMONIKON'. Diocles too seems to have used the word HĒGEMŌN of the intellectual principle, which he placed in the heart.⁷³ The word is used several times of the rational principle of the soul by Plato in the *Timaeus* (41C, 44A, 45B) and Aristotle⁷⁴ applied the adjective to the front of the body, and hence to the 'great blood vessel' or vena cava, which lies forward—as indeed the heart does. Neither the word nor the idea are new. But the Stoics made this sense of the word peculiarly their own, and from them it became part of the technical vocabulary of philosophers. But it is of small importance how far back we can trace the idea of

⁷⁰ SVF I, 499ff.; cf. von Arnim in RE XI, 1 col. 565.

⁷¹ *De Natura Deorum* II 40–41 = SVF I, 504.

⁷² Cicero ND III, 37 = SVF I, 501: *ali autem solem . . . eamque causam Cleanthes adfert cur se sol referat nec longius progrediatur solstitiali orbi itemque brumali, nec longius discedat a cibo.* Notice however that the same explanation of the sun's movement was given by Diogenes of Apollonia (DK 51A17); and cf. *de Flatibus* ch. 3.

⁷³ Fuchs 5.543 Fr. 59 Wellman. Jaeger, *Diokles*, p. 215 has some doubts that this is Diocles' own expression.

⁷⁴ PA 667B35.

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intellect as HĒGEMŌN. What is of significance however is the implicit analogy between sun-HĒGEMŌN and left heart-HĒGEMŌN in respect of their nutrition by exhalation in 'On the Heart'—significant precisely because it is implicit. The author feels no need to spell out the details for us—any more than, in another context (see above), he feels a need to spell out the details of why the pulmonary artery is an artery. To him, these are quite familiar matters, which have small significance for his immediate purpose to which, with characteristic sobriety, he sticks. So far as the evidence goes, he may indeed have written before Cleanthes.⁷⁵ But the manner, the *style*, suggests a time at which Cleanthes, and perhaps others, had made the idea common property.⁷⁶

⁷⁵ Cleanthes was of course not the first to compare vital heat to the heat of the sun. Apart from the fact that it is an idea which might readily occur to the visceral imagination of human beings at any time, there is the famous passage in Aristotle in which connate pneuma is described as a substance analogous to that of the heavenly bodies (GA 2.3, 736B30ff). Xenophon's Socrates, disagreeing with Anaxagoras who regarded the sun as 'just fire', remarked on the difference, in respect of its *vitalizing* properties, between the heat of the sun and the heat of the fire. Cf. A. S. Pease on Cicero, *De Natura Deorum* 2.40, where these and other references are given. And of course the comparison has to be set in its context of ancient analogies between macrocosm and microcosm. The Hippocratic treatise 'On Sevens' is interesting here. In chapter 6 the veins and the blood in them, in the microcosm, correspond to rivers in the macrocosm, just as they do in 'On the Heart' ch. 7; and possibly—the text is difficult to make out—an analogy between heart and sun is hinted at. In ch. 15 of the same work the heat of the sun is the cause of growth and *movement* in all things (crementum et motus omnibus). The date and provenance of 'On Sevens' is however quite uncertain. Even more striking is 'On Diet' 1.10 (VI, 484–86 Littré): animal heat = sun's fire and is 'soul, intellect, intelligence, movement, increase and decrease'. (cf. the similar list of characteristics in Cicero, *Nat. Deor.* 2.40 quoted above).

But what we have explicitly in Cleanthes and implicitly in 'On the Heart' is a quite systematic comparison between the nutrition by ANATHUMIASIS of the sun and of the vital heat, which implies a definite physiological doctrine.

⁷⁶ Kudlien, *op. cit.*, p. 424ff. remarks that since Posidonius can now be definitely brought into connexion with the Pneumatic school, it is at least not absurd to suspect a connexion between 'On the Heart' and the 'Posidonian' doctrines for which K. Reinhardt argues; though wisely Kudlien does not commit himself on the rightness of Reinhardt's arguments. The facts are these: there is certainly in the late sources a quite explicit analogy between sun and heart; moreover, this analogy is physiological. The earliest direct and explicit analogy is in Plutarch, *De Facie in Orbe Lunae* ch. 15, where the sun (a) dispenses light and warmth to the cosmos, just as the heart dispenses blood and pneuma to the body; (b) is nourished by exhalations from earth and sea, just as the heart is nourished from the organs beneath it; (c) has its nourishment purified by the moon, (which in turn moderates the heat sent down by the sun), just as the heart has its nourishment purified by the liver. On this and later passages, particularly Macrobius I, 20, 6 (the sun is called 'cor caeli') see K. Reinhardt, *Kosmos und Sympathie*, 330ff. and RE XXII, I, col. 692ff. Reinhardt elaborately argues that Plutarch represents, in a modified form, the doctrine of Posidonius. But whether by Posidonius or not, the physiological analogy (the physiology is Erasistratean, says Reinhardt in RE XXII, I, col. 695) is fully developed by the end of the first century A.D. My own view is that Reinhardt is right in seeing Posidonian material in the Plutarch passage, but this is always a contentious matter, and in any case we do not know the extent of Posidonius' debt to Cleanthes. But, as Kudlien says, it would not be absurd to place 'On the Heart' as late as Posidonius: cf. also what I have said at the beginning about the word PHŌTOEIDĒS. However the fact that 'On the Heart' describes only two valves, not four, is a difficulty. It would help a little if we knew for certain whether the Pneumatic School recognized all four valves, and also whether they accepted Herophilus' terminology of 'venous artery' and 'arterial vein' for the pulmonary vein and pulmonary artery. The terms do not appear in Aretaeus.

Posidonius, or at least the Stoics, comes up again in connexion with a passage in Vindicianus, *De Semine* ch. 17, p. 219 Wellmann. Here too there is a comparison of the heart to the sun, not however in respect of its nutrition, but in respect of the way in which the power of the soul makes itself felt in all parts of the body, by 'radiating', like the sun, from the heart: 'sic enim supradicto exemplo ignei splendoris seu radii ex partibus loci in corde constituti, in quo anima consistit, usque ad omnes fines corporis nostri superveniet, et consensus in illis partibus fiet, in quibus etiam irruentia perficiuntur'. Wellmann (pp. 46–47) finds the influence of Diocles in the passage, but there is no reason for doing so. The last authority to be mentioned by Vindicianus before this passage is Hippocrates (in ch. 13), and in any case there is a break in continuity, in Vindicianus' text, between the beginning of ch. 17 and what has preceded ('igitur cor': but what has this to do with the development of the embryo, the subject of ch. 16?) Nor is there any antecedent in the Vindicianus passage as it stands

RETROSPECT

The intention of the present essay has been to canvass dispassionately a number of possibilities; to suggest grounds for rejecting some and approving others; and to subject certain aspects of 'On the Heart' to a more searching examination than they have perhaps received hitherto. It is better to travel than to arrive; to deepen one's understanding of the problem than to draw spuriously precise conclusions. But hypothetical conclusions may after all be regarded as merely another way of stating the problem. In that sense, then, what are the conclusions which we may provisionally draw about the date and affiliations of the treatise? The reasons for dating it not earlier than the middle or late fourth century B.C. are overwhelming, and are hardly disputed. The question is rather how much later it should be placed. A date in the third century would suit the relative degree of anatomical sophistication which we notice in the treatise, particularly in the matter of veins and arteries. On the other hand, the author cannot be regarded as a direct pupil of either Herophilus or Erasistratus: there are too many divergences from both, and on matters which are too important. Further, an examination of the text makes it reasonably certain that the author recognizes the working of only two valves, not four. In view of the author's evident aim to draw a teleological moral, this fact is a strong objection to dating it much after Erasistratus—assuming, what seems to be the case, that the beauty and economy of Erasistratus' conception was all but universally accepted and was irreversible.⁷⁷ And the fact that the author does recognize at least the semilunar valves does not conflict, as we have seen, with Galen's attribution of the discovery of the valves to Erasistratus, since what Erasistratus discovered was the co-ordinated function of all four valves. On the whole, a date in the first half of the third century B.C.—late enough for the author to have some knowledge of Stoicism—while not entirely congenial, would seem to create the fewest problems. If so, the treatise would be an invaluable index to the state of anatomy and physiology shortly prior to the work of the great Alexandrians Herophilus and Erasistratus. In particular it would prefigure, though it cannot be by much, the 'classical' portrait of the heart which we associate with Erasistratus, and then Galen.

for *supradicto exemplo* in ch. 17. The source of the comparison in ch. 17 may well be Stoic: the idea of the extension of the HEGEMONIKON to all parts of the body is certainly Stoic, an idea which they had a particular predilection for illustrating with striking comparisons. Notice too the word 'consensus', presumably a translation of Greek SUMPATHEIA or SUMPHONIA, a key concept in Stoicism. The same may be said even more surely of Vindicianus ch. 18 (the faculty of sense is a unity, which alters its character according to the different sensory channels in which it is active) and ch. 19: sicut, inquit, ignis . . . sic etiam anima in cordis altitudine habens rationabilem virtutem, quae tendit usque ad corporis fines, omnes sensus perficit—pure Stoicism—and 'accedit etiam quod secum plurimum luminis ex anima trahat [sc. sensifica virtus] [atque] ex corde perfecto in similitudinem radii per visificas vias irruat etc.' This is simply the doctrine that sight is a modification of the HEGEMONIKON which sees by acquiring the nature of light: that is, the doctrine for which Posidonius, as noted above, found the word PHOTOEIDES so useful, and which is expressed in Cicero *De Natura Deorum* II and in several Stoic passages. The presence of Stoic views on sensation would not be surprising in Vindicianus: his source is very probably Soranus (cf. Wellmann, pp. 6ff.; Jaeger, Diokles p. 187ff; Deichgräber, RE IXA, 1, sv. Vindicianus col. 34; cf. col. 36 where he stresses the Stoic-pneumatic content of Vindicianus), who wrote a book 'On the Soul', which was used by Tertullian as a source for his *De Anima* (cf. RE IIIA, 1, s.v. Soranus, col. 1115). There is therefore no reason for attributing these passages about light in Vindicianus to Diocles. Yet this was one of Wellmann's better arguments for seeing a relation between Diocles and 'On the Heart'.

⁷⁷ This then emerges as the most cogent reason against giving the treatise a date in the first century B.C.—which would otherwise appear not implausible.

The Paradoxical Text 'On the Heart'

And that point, indeed, underlines the paradox of such attempts at dating: the apparently fixed points by which we initially attempt to locate a particular work may themselves become changed in the process. But we may also reasonably hope that their contours will become clearer. Thus the question of date offers a convenient approach to other, more fruitful, problems. The treatise 'On the Heart', apart from its intrinsic value, also has the value of a surveying instrument. It serves to give bearings, and to bring into sharper focus a number of problems in Alexandrian medical science: for example the distinction between veins and arteries in Herophilean anatomy, the nature of Erasistratus' discovery of the valves, the meanings of 'mechanism' in Greek science, and the effect of teleological assumptions upon the accuracy of anatomical observation. All these are matters worth pursuing for their own sake.

NEW FILMS ON THE HISTORY OF MEDICINE

Two short films in the history of medicine have recently been produced by Dr. Thomas R. Forbes. *John Hunter—Enlightened Empiricist* (11 minutes), shown on 5 May 1972, at the meeting of the American Association for the History of Medicine in Montreal, presents Hunter as an anatomist and surgeon. His application of his knowledge of collateral circulation for the successful surgical relief of a coachman's popliteal aneurysm is portrayed as an example of his ability to reject dogma and to apply in a clinical situation lessons learned at the dissecting table.

Vesalius, Founder of Modern Anatomy (12 minutes), reveals the colourful Belgian's progress from Galenism to a new and more accurate knowledge of anatomy through his own labours as a dissector. Examples of his scientific thinking are drawn from the text and illustrations of the *Fabrica*.

The 16 mm. films in sound and colour were specially designed to interest medical and nursing students, members of the health professions, biologists, and historians, and were made by Miss Susan Wheeler and Mr. William Guth of the Communications Media Group of the Yale School of Medicine. Costs were met from a grant from the National Fund for Medical Education. Prints at \$40.00 each may be ordered by writing to Mr. William Guth, Communications Media Group, School of Medicine, Yale University, New Haven, Conn. 06510, U.S.A.