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BLOOD FLOW IN ARISTOTLE*

Modern readers view ancient theories of blood flow through the lens of circulation. Since the nineteenth century, scholarly work on the ancient understanding of the vascular system has run the gamut from attempting to prove that an ancient author had in fact, to some extent or another, pre-empted Harvey's discovery of the circulation of the blood[1] or towards attempting, often with some empathetic embarrassment, to explain the failure on the part of an ancient author to notice something that seems so obvious to the modern eye.[2] Thus C.R.S. Harris's 1973 book *The Heart and Vascular System in Ancient Greek Medicine*, which remains the standard on the topic, opens with a sentence in which he marvels at how the otherwise admirable ancient Greek physicians could have 'failed entirely to arrive at any conception of the circulation of the blood'.[3] This modern vantage point has had an unfortunate effect. In the case of Aristotle in particular, understanding of his cardiovascular system has been diminished by a tendency to define it in contradistinction to our own modern understanding of circulation. By deliberately uncoupling from the framework of modern physiology, this paper will offer a richer and more accurate picture of his views.

To be fair, Aristotle did not help matters much. In *Parts of Animals* 3.4, he says definitively (Passage 1) (*Part. an.* 666a6–8):

ἐκ τῆς καρδίας γὰρ ἐποχετεύεται καὶ εἰς τὰς φλέβας, εἰς δὲ τὴν καρδίαν οὐκ ἄλλοθεν· αὕτη γάρ ἐστιν ἀρχὴ ἢ πηγὴ τοῦ αἵματος καὶ ὑποδοχὴ πρώτη.

[Blood] is conducted out of the heart and into the veins, not from elsewhere into the heart; for this is the source or spring of the blood and its first receptacle.

* I presented earlier drafts of this paper at the London Ancient Science Conference in February 2017 and at the Annual Meeting of the Society for Ancient Greek Philosophy in October 2017. I am grateful for the feedback from those audiences and for the helpful comments of Patrick Finglass and the anonymous reviewer at *CQ*, as well as to Mark Schiefsky for early conversations. All translations are my own.

[1] E.g. É. Littré, *Œuvres complètes d'Hippocrate* (Paris, 1839–61), 1.222–3; R. Kapferer, *Die anatomischen Schriften, die Anatomie, das Herz, die Adern, in der Hippokratischen Sammlung* (Stuttgart, 1951), 15–55; P. Ghalioungui, 'The West denies Ibn Al-Nafis's contribution to the discovery of the circulation', in A.R. Jundi and H.M. Zahoorul Hasan (edd.), *Second International Conference on Islamic Medicine* (Kuwait City, 1982), 299–304.

[2] E.g. C.R.S. Harris, *The Heart and Vascular System in Ancient Greek Medicine* (Oxford, 1973), 109 on Praxagoras' 'tragical mistake . . . which more than almost any other prevented the discovery of the circulation' and J.R. Shaw, 'Models for cardiac structure and function in Aristotle', *JHB* 5 (1972), 355–88, at 355–6, who, after framing Aristotle as 'ignorant of both circulation and respiration', laments that his interpretation of the heart's function was 'so mistaken and confused . . . that it is impossible to get a clear picture from his authentic works'.

[3] Harris (n. 2), 1.

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This statement positively begs to be compared to circulation. It lends heavy weight to statements such as Michael Boylan's that 'there is no return of blood . . . Aristotle's circulatory system, apart from the input from the digestive system, is a one-way system: blood moves from the heart to the uniform and non-uniform parts that require nourishment'.[4] Yet, a survey of the Aristotelian corpus indicates that this is not, in fact, an accurate description of his theories. Instead, the broader context indicates that the statement in Passage 1 above refers to the *origins* of the blood rather than to its subsequent movements through the heart and vascular system, which, though decidedly not circulatory, are at the very least circuitous: blood, in Aristotle's model, flows both into and out of the heart. Thus reading Passage 1 without an implicit comparison to circulation reveals that the generally agreed upon characterization of his model—that it entails the unidirectional flow of blood out of the heart and its subsequent and immediate absorption into the body—is unfounded and inaccurate. A new characterization is required.

VASCULAR SYSTEM

To understand the flow of blood in the Aristotelian vascular system, we must first understand the arrangement of that system and the nature and origin of blood. To begin with the system, Aristotle is clear that the heart is the source and centre of the blood vessels.[5] His descriptions of the heart itself, however, are contradictory, both among themselves and in relation to observable fact. Attempts to reconcile Aristotle's descriptions and map them onto the anatomy of the actual organ began in antiquity and continue through modern scholarship: an irresistible yet bedevilled project.[6] Fortunately, it is possible

[4] M. Boylan, 'The digestive and "circulatory" systems in Aristotle's biology', *JHB* 15 (1982), 89–118, at 118. Compare W. Ogle, *Aristotle on The Parts of Animals. Translated with Introduction and Notes* (London, 1882), 193 n. 5: 'in calling the heart origin or centre of the vessels, A. implies two things: firstly, that it is the place where the blood is made; and, secondly, the place whence blood, when thus made, is propelled into the vessels, blood going from it, but none returning to it'; D. Lanza and M. Vegetti, *Opere biologiche di Aristotele* (Turin, 1971), 550: 'non c'è communque in quest'opera alcuna idea della circolazione del sangue, il cui flusso è sostanzialmente a senso unico, dal centro alla periferia' (cf. at 648); Harris (n. 2), 135: 'blood flows from the heart to the other parts of the body, it does not come to the heart from elsewhere. No circulation for the Master of those that Know'; R.E. Siegel, 'Principles and contradictions in the evolution of Hippocrates', Aristotle's and Galen's doctrines of respiration and blood flow', *Episteme* 9 (1975), 171–88, at 175: 'all the blood was used up peripherally and never returned'; P. van der Eijk, *Aristoteles. De insomniis, De diuinatione per somnum* (Berlin, 1994), 83–4: 'Aristoteles fast nirgends von einem Rückfluß des Blutes zum Herzen spricht: im Gegenteil, das Blut kommt aus dem Herzen hervor und verteilt sich zu den Organen und Geweben, denen es zu Nahrung dient; von einer Rückkehr des Blutes findet sich bei Aristoteles sonst nirgends eine Spur'; J.G. Lennox, *Aristotle On the Parts of Animals I–IV. Translated with Introduction and Commentary* (Oxford, 2001), 257 (ad loc.): 'Aristotle gives no indication why he is so sure that blood flows *from* the heart *into* the blood vessels but not vice versa'; P. Louis, *Aristote. Histoire des Animaux* (Paris, 2002[2]), 77 n. 1 (ad loc.): 'comme on le voit Aristote ne soupçonnait pas le méchanisme de la circulation sanguine'; C.M. Oser-Grote, *Aristoteles und das Corpus Hippocraticum. Die Anatomie und Physiologie des Menschen* (Stuttgart, 2004), 125: 'vom Herzen also . . . ergießt sich alles Blut in die Adern, aber keinerlei Blut fließt wieder in dieses zurück'; S. Zierlein, 'Aristoteles' anatomische Vorstellung vom menschlichen Herzen', *Antike Naturwissenschaft und ihre Rezeption* 15 (2005), 43–71, at 47: '[das Herz] gebe Blut in die Adern, ohne irgendwoher Blut zu empfangen'.

[5] *Hist. an.* 513a22; *Part. an.* 665b14–21; *Resp.* 474b8.

[6] Harris (n. 2), 121–76 summarizes the various attempts, now updated by Zierlein (n. 4), which provides an analysis of the differences among Aristotle's accounts and their discrepancies from the actual anatomy. See now L. Dean-Jones, 'Aristotle's heart and the heartless man', in J.Z. Wee

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to address the matter at hand without first having to resolve the thorny question of his anatomical accuracy; more important for the discussion of blood flow is the far less controversial question of how he connects the chambers of the heart to each other and to the rest of the body.

Aristotle gives four distinct descriptions of cardiac anatomy, two in *History of Animals*, one in *Parts of Animals* and one in *On Sleep*.[7] I begin with the two passages from *History of Animals*, both vexed by textual difficulties. In the first, he tells us (Passage 2) (*Hist. an.* 496a4, 20–7):

ἡ δὲ καρδία ἔχει μὲν τρεῖς κοιλίας . . . μεγίστην μὲν τὴν ἐν τοῖς δεξιοῖς, ἐλαχίστην δὲ τὴν ἐν τοῖς ἀριστεροῖς, μέσην δὲ μεγέθει τὴν ἀνὰ μέσον· ἔχει δὲ τὰς δύο μικράς· καὶ εἰς τὸν πλεύμονα τετρημένας ἁπάσας, κατάδηλον δὲ κατὰ μίαν τῶν κοιλιῶν. κάτωθεν δ' ἐκ τῆς προσφύσεως κατὰ μὲν τὴν μεγίστην κοιλίαν ἐξήρτηται τῇ μεγάλῃ φλεβί, πρὸς ἣν καὶ τὸ μεσεντέριόν ἐστι, κατὰ δὲ τὴν μέσην τῇ ἀορτῇ.

The heart has three chambers . . . the largest one on the right side, the smallest on the left, and the middle-sized one in the middle. It has two small [chambers] and all of them are perforated through to the lung and this is clear in respect to one of the chambers. And out from below the point of attachment [to the lungs], from the largest chamber it is attached to the great vein, to which the mesentery too [attaches], and from the middle [chamber] to the aorta.[8]

In the next iteration, he reaffirms the three-cavity structure of the heart, though adding that in smaller animals only one or two are visible. He then adds more details (Passage 3) (*Hist. an.* 513a32–b7):

ἡ μεγίστη μὲν κοιλία ἐν τοῖς δεξιοῖς καὶ ἀνωτάτω αὐτῆς, ἡ δ' ἐλαχίστη ἐν τοῖς ἀριστεροῖς, ἡ δὲ μέση μεγέθει τούτων ἐν τῷ μέσῳ ἀμφοῖν· ἀμφότεραι δὲ αἱ δύο πολλῷ ἐλάττους εἰσὶ τῆς μεγίστης. συντέτρηνται μέντοι πᾶσαι αὗται πρὸς τὸν πλεύμονα, ἀλλ' ἄδηλοι διὰ σμικρότητα τῶν πόρων πλὴν μιᾶς. ἡ μὲν οὖν μεγάλη φλὲψ ἐκ τῆς μεγίστης ἤρτηται κοιλίας τῆς ἄνω καὶ ἐν τοῖς δεξιοῖς, εἶτα διὰ τοῦ κοίλου τοῦ μέσου γίνεται πάλιν φλέψ, ὡς οὔσης τῆς κοιλίας μορίου τῆς φλεβὸς ἐν ᾧ λιμνάζει τὸ αἷμα. ἡ δ' ἀορτὴ ἀπὸ τῆς μέσης· πλὴν οὐχ οὕτως ἀλλὰ κατὰ στενοτέραν σύριγγα πολλῷ κοινωνεῖ. καὶ ἡ μὲν φλὲψ διὰ τῆς καρδίας, ἡ δ' ἀορτὴ ἀπὸ τῆς καρδίας τείνει.

The biggest chamber is on the right side and in the highest part of the heart, the smallest is on the left side, and the middle-sized of the chambers is in between the pair of them. And these latter two are much smaller than the biggest. However, they are all perforated together into the lung, but not obviously so, except for one, because of the smallness of the passages. The great vein is hung upon the largest chamber (the one above and to the right), then [having passed] through the intermediary cavity it becomes again a vein, as if the chamber were a part of the vein in which the blood pools. The aorta [comes] from the middle chamber, except not in the same way, rather it joins on a much narrower pipe. And the vein stretches through the heart, but the aorta from it.[9]

(ed.), *The Comparable Body: Analogy and Metaphor in Ancient Mesopotamian, Egyptian, and Greco-Roman Medicine* (Leiden, 2017), 122–41, which proposes a new interpretation of these texts on a fetal model.

[7] *Hist. an.* 496a4–34, 513a27–b7; *Part. an.* 666b1–667a11; *Somn.* 458a15–19.

[8] Following the text in D.M. Balme, *Aristotle Historia Animalium Volume I Books I–X: Text. Prepared for publication by Allan Gotthelf* (Cambridge, 2002).

[9] Text from Balme (n. 8), except for the final sentence, which is emended along the lines of the popular conjecture found in two sixteenth-century editions. For a detailed discussion of the translation of this passage, see C. Bubb, 'Hollows in the heart: a lexical approach to cardiac structure in Aristotle', *Sudhoffs Archiv* 103 (2019), 128–40 with a note on the emended sentence at n. 7.

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The situation changes when we turn to *Parts of Animals*. Here Aristotle asserts that the actual rather than apparent number of chambers in the heart varies from one to three depending on the size of the animal, with three being the ideal number. Three is ideal, because it allows for optimal functional arrangement: one chamber is required at minimum to contain the blood; two chambers is better so that each of the two main vessels, which are different in nature, can have its own, different, source; three is best so that these two sources can have one common source, which is the middle and 'odd' one.[10] He adds (Passage 4) (*Part. an.* 666b35–667a6):

τούτων δὲ πλεῖστον μὲν αἷμα καὶ θερμότατον ἔχουσιν αἱ δεξιαί (διὸ καὶ τῶν μερῶν θερμότερα τὰ δεξιά), ἐλάχιστον δὲ καὶ ψυχρότερον αἱ ἀριστεραί, μέσον δ' αἱ μέσαι τῷ πλήθει καὶ θερμότητι, καθαρώτατον δέ· δεῖ γὰρ τὴν ἀρχὴν ὅτι μάλιστ' ἠρεμεῖν, τοιαύτη δ' ἂν εἴη καθαροῦ τοῦ αἵματος ὄντος, τῷ πλήθει δὲ καὶ θερμότητι μέσου.

Of these [chambers], the right ones have the most and hottest blood (wherefore the right parts of the body are also hotter), the left have the least and the coldest, and the middle ones have blood that is medium in respect to quantity and heat, and it is purest. For the source ought to be as calm as possible and it can be this way when the blood is pure and intermediate as to quantity and heat.

Though he does not explicitly say so here, it would seem that he has switched the connection of the aorta to the left chamber rather than to the middle, as in *History of Animals*. He appears to describe a central chamber connected to the other two, which are then connected to their respective vessels.

Finally, the fourth description of the heart in *On Sleep* makes the suggestion in *Parts of Animals* explicit (Passage 5) (*Somn.* 458a15–19):

παντὸς δὲ τοῦ αἵματος ἀρχή, ὥσπερ εἴρηται καὶ ἐνταῦθα καὶ ἐν ἄλλοις, ἡ καρδία. τῶν δ' ἐν τῇ καρδίᾳ ἑκατέρας τῆς θαλάμης κοινὴ ἡ μέση· ἐκείνων δ' ἑκατέρα δέχεται ἐξ ἑκατέρας τῆς φλεβός, τῆς τε μεγάλης καλουμένης καὶ τῆς ἀορτῆς· ἐν δὲ τῇ μέσῃ γίνεται ἡ διάκρισις.

The source of all blood, as has been said both here and in other treatises, is the heart. Of the chambers in the heart, the middle is common to the others. Each of the others receives [blood] from each of the vessels, the one called great and the aorta; in the middle chamber, the separation occurs.[11]

Though the two descriptions in *History of Animals* are more tantalizingly close to being reconcilable with anatomical fact, the descriptions in *Parts of Animals* and *On Sleep* adhere better to Aristotle's theoretical biological framework, providing a single and

[10] *Part. an.* 666b21–34: ἔτι δὲ βέλτιον τρεῖς εἶναι τὰς κοιλίας, ὅπως ᾖ μία ἀρχὴ κοινή· τὸ δὲ μέσον καὶ περιττὸν ἀρχή.

[11] That is, in keeping with the cardiac description in *Part. an.*, each chamber connects to its own vessel, i.e. the great vein to the right and the aorta to the left; this is the standard interpretation (cf. W.S. Hett, *Aristotle On the Soul, Parua Naturalia, On Breath* [Cambridge, MA, 1957], 343; G.E. R. Lloyd, 'The empirical basis of the physiology of the *Parua Naturalia*', in id., *Methods and Problems in Greek Science* [Cambridge, 1991], 224–47, at 231; D. Gallop, *Aristotle On Sleep and Dreams* [Warminster, 1996], 83). Recently both Zierlein (n. 4), 51 and Dean-Jones (n. 6), 136 have independently argued that it should be interpreted as both vessels connecting with both chambers, but this renders the anatomy quite complicated and is at odds (as Zierlein indeed highlights) with the statement at *Part. an.* 666b27–9 that each of the two vessels should have its own, distinct, origin. The Greek by no means demands this alternative and more difficult translation; compare, for example, *Hist. an.* 515a1–2 and 564a20–4, where this same grammatical construction should clearly be interpreted in the way I suggest.

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central source for the blood and thus also, potentially, for the soul. As a result of this, and also because the texts that contain them are more concerned with what we would today call physiology than *History of Animals* is, this latter model will dominate in the discussion of blood flow patterns, leaving us with a working model somewhat along the lines delineated in Figure 1.[12]

The next task is to follow the aorta and the great vein (today's *uena caua*) as they branch out and extend to the rest of the body, creating the entire vascular system. The great vein and the aorta are the only two blood-admitting vessels that connect directly to the heart.[13] Each of them extends both above and below it, the great vein, as we saw in the second description of the heart, incorporating one of the chambers in its path, the aorta seemingly connected by an offshoot. To quote *Parts of Animals*, 'the remaining vessels are outgrowths of these'.[14] By synthesizing the various scattershot descriptions of the organs and the vascular system in *History of Animals*, *Parts of Animals* and *Generation of Animals*, I arrive at the schema laid out in Figure 2.[15]

With the exception of the omentum, the bladder and, depending which text you consult, the liver, spleen and uterus, each of the organs is connected to both of the main vessels.[16] Further, though the arms, for reasons connected to established medical practices, are accessible from both above and below the heart, for all the rest of the body the only path from the organs below the heart to the organs above it requires passing through the heart itself. Having established the infrastructure, so to speak, let us proceed to the contents.

[12] As my hybrid approach to cardiac anatomy here indicates (as will the soon-to-follow treatment of the blood vessels), Aristotle approaches the details and workings of the cardiovascular system in a scattershot and sometimes self-contradictory way. It is therefore worth considering whether it is reasonable to hope to put together one definitive model of blood flow that he consistently applies across all of the texts. While I am cautious of attempting to present here a positive model for how precisely he conceived of the flow of blood in the body in every instance—such a thing is surely not feasible at any great level of detail—the evidence from across the corpus appears to uniformly indicate that, whatever his model *is*, it is consistently *not* compatible with a unidirectional flow of blood out of the heart. (Note that I have not included in Figure 1 the 'perforations' into the lung—Aristotle presents these perforations as allowing for the passage of air rather than for that of blood [*Hist. an.* 495b12–16, 496a31–2], making them irrelevant to the present discussion.)

[13] Some interpreters have suggested that Aristotle also conceived of pulmonary vessels that directly connect the heart to the lungs (Harris [n. 2], 154–8 provides an overview of the main arguments). This is by no means certain—indeed, the passage quoted in the subsequent note would rather seem to deny it—but, even if it were the case, it would not materially change the argument presented here, so I have left the rather vexed question of pulmonary blood flow, which I address in more detail in Bubb (n. 9), to the side.

[14] *Part. an.* 667b15: αἱ δὲ λοιπαὶ τούτων ἀποφυάδες εἰσίν.

[15] The main description of the paths of the great vein and aorta is found at *Hist. an.* 513b12–515a15; additional information occurs at *Hist. an.* 496b29–497a5; *Part. an.* 670a14–18, 672b7, 677b36–678a26; and *Gen. an.* 738a10–27.

[16] In *Hist. an.* Aristotle positively asserts that there are no connections between the aorta and the liver and spleen (514b28–9) or between the great vein and the uterus (515a5–7). However, in *Part. an.* he appears to claim that there are connections between both vessels and the liver and spleen (670a14–18), though it should be noted that, while the flow of ideas in this passage favours this interpretation (see, for example, the translation in Lennox [n. 4], 64 [ad loc.]), Louis (n. 4), 88–9 has tried to reconcile the account here with that in *Hist. an.* by assigning these connecting offshoots of the two vessels rather to the kidneys, which are also mentioned parenthetically in this sentence. Similarly, and less ambiguously, Aristotle connects both vessels to the uterus at *Gen. an.* 738a10–12.

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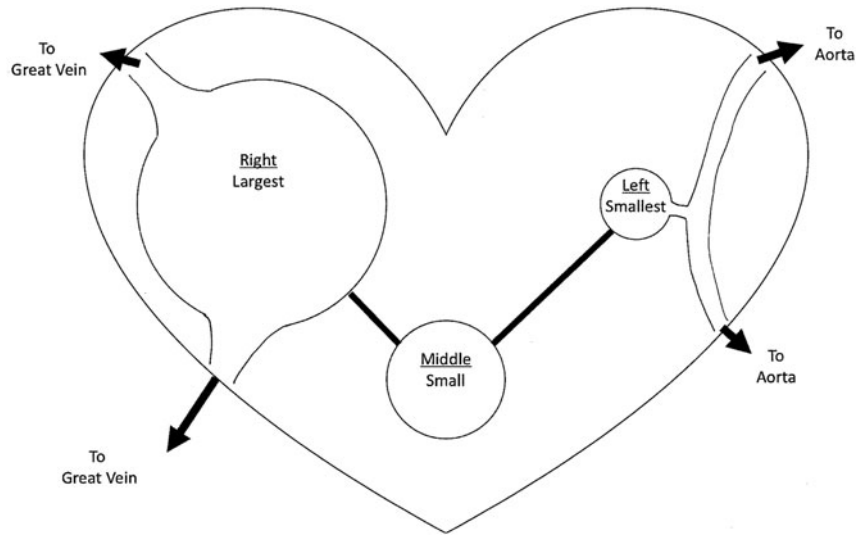


FIGURE 1: Working model of the heart in Aristotle

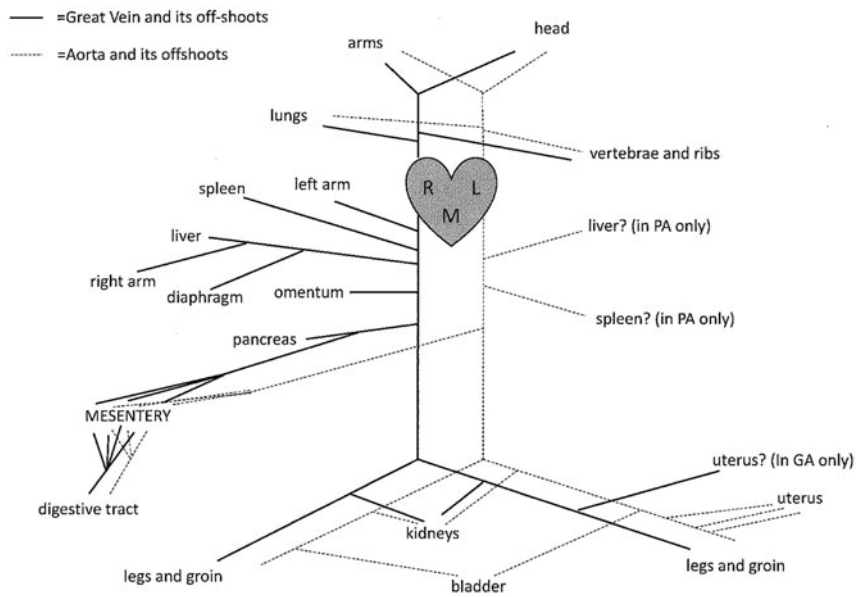


FIGURE 2: Working model of the vascular system in Aristotle

BLOOD

The purpose of the heart and vascular system, Aristotle repeatedly states, is to contain the blood. Blood is essential to the life of the animal because it is the final form of nutriment; in other words, it represents the last step in assimilating ingested food into

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a substance that can be used to create, grow or maintain any part of the body. Thus blood is the end-product of the digestive system (of which the heart is the final organ).[17] Its final fate will be either to become flesh or to be further concocted into a residue like fat, milk or semen. Aristotle is quite explicit that blood is essentially just food that has been altered by concoction. He indicates at various points that the quality and quantity of the blood and the parts made from it are directly proportional to the quality and quantity of ingested food.[18] Thus it is clear that nutritive material must enter the heart in order for the blood to be created and in turn to come out. And, in light of the vascular arrangement just sketched, the influx and the efflux necessarily occur along the same channels.

Unfortunately, Aristotle's work *On Nutrition*, to which he refers repeatedly, does not survive.[19] It is nevertheless possible to cobble together an outline of his views on digestion, which is to say blood formation, from remarks in other texts. In an extended simile to plant roots in *Parts of Animals*, he lays out the connection of the digestive tract to the vascular system (Passage 6) (*Part. an.* 650a14–31):

ὥσπερ δὲ καὶ τὸ στόμα τῆς ἀκατεργάστου τροφῆς πόρος ἐστί . . . οὕτως καὶ ἄλλας ἀρχὰς δεῖ πλείους εἶναι, δι' ὧν ἅπαν λήψεται τὸ σῶμα τὴν τροφήν, ὥσπερ ἐκ φάτνης, ἐκ τῆς κοιλίας καὶ τῆς τῶν ἐντέρων φύσεως. τὰ μὲν γὰρ φυτὰ λαμβάνει τὴν τροφὴν κατειργασμένην ἐκ τῆς γῆς ταῖς ῥίζαις (διὸ καὶ περίττωμα οὐ γίνεται τοῖς φυτοῖς· τῇ γὰρ γῇ καὶ τῇ ἐν αὐτῇ θερμότητι χρῆται ὥσπερ κοιλίᾳ), τὰ δὲ ζῷα πάντα μὲν σχεδόν, τὰ δὲ πορευτικὰ φανερῶς, οἷον γῆν ἐν αὑτοῖς ἔχει τὸ τῆς κοιλίας κύτος, ἐξ ἧς, ὥσπερ ἐκεῖνα ταῖς ῥίζαις, ταῦτα δεῖ τινι τὴν τροφὴν λαμβάνειν, ἕως τὸ τῆς ἐχομένης πέψεως λάβῃ τέλος. ἡ μὲν γὰρ τοῦ στόματος ἐργασία παραδίδωσι τῇ κοιλίᾳ, παρὰ δὲ ταύτης ἕτερον ἀναγκαῖον λαμβάνειν, ὅπερ συμβέβηκεν· αἱ γὰρ φλέβες κατατείνονται διὰ τοῦ μεσεντερίου παράπαν, κάτωθεν ἀρξάμεναι μέχρι τῆς κοιλίας.

And just as the mouth is a channel for the unprocessed nourishment, . . . so there must also be many other sources, through which the entire body will take its nourishment, as if from a trough, out of the stomach and the nature of the intestines. Plants take their nourishment already worked up out of the earth with their roots (wherefore plants do not produce waste products; for they use the earth and its heat like a stomach), but just about all animals, and obviously so those which have locomotion, have, like an earth inside them, the vessel of the stomach, out of which, just as plants with their roots, the animals must take the nourishment with something, until it reaches the end of its digestion. For the production of the mouth transmits to the stomach, from which it is necessary that something else pick it up, which is what happens; for veins stretch all throughout the mesentery, starting from below [and stretching] up to the stomach.

There are two complementary systems at work here. In the first, the food enters the mouth and is successively worked upon and altered by the organs of the digestive tract. When it exits the stomach and enters the jejunum at the beginning of the small intestine, Aristotle tells us that the food here 'changes and is no longer still fresh nor is it yet excrement'.[20]

At this point the veins from the mesentery somehow siphon off the useful product and usher it into the second system, the vascular, while the remaining solid waste continues down the first, digestive, system and out the other side. Aristotle declines

[17] On the heart as the final and most important organ of the digestive system, see *Juv.* 468b31–469a10.

[18] See especially *Part. an.* 650a32–b1, 651a12–17; *Gen. an.* 786a35–b6; *Resp.* 474a25–b9.

[19] On the references to this text, together with a theory for its absence from the modern corpus, see P. Louis, 'Le traité d'Aristote sur la nutrition', *RPh* 26 (1952), 29–35.

[20] *Part. an.* 675b29–36: μεταβάλλει καὶ οὔτ' ἔτι πρόσφατος οὔτ' ἤδη κόπρος.

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to describe the precise mechanism of transference of the nutriment from the intestines to the veins in *Parts of Animals*, beyond reiterating the roots simile and underscoring that it is the responsibility of the mesentery, which is 'full of many densely packed veins, which stretch from the intestines to the great vein and the aorta'.[21] For the details, he refers us to *On Generation*, which does not address it, and *On Nutrition*, which we do not have. As a result, we are solely dependent on the brief description in *On Sleep* (Passage 7) (*Somn.* 456a34–b6):

τροφὴ δ' ἐστὶ πᾶσιν ἡ ἐσχάτη . . . ἡ τοῦ αἵματος φύσις . . . τόπος δὲ τοῦ αἵματος αἱ φλέβες, τούτων δ' ἀρχὴ ἡ καρδία . . . τῆς μὲν οὖν θύραθεν τροφῆς εἰσιούσης εἰς τοὺς δεκτικοὺς τόπους γίγνεται ἡ ἀναθυμίασις εἰς τὰς φλέβας, ἐκεῖ δὲ μεταβάλλουσα ἐξαιματοῦται καὶ πορεύεται ἐπὶ τὴν ἀρχήν. εἴρηται δὲ περὶ τούτων ἐν τοῖς Περὶ τροφῆς.

The final form of nutriment for all creatures is the nature of blood . . . and the location of the blood is the veins, and the source of those is the heart . . . and when the nutriment enters the receptive parts from without, an exhalation comes about from it into the veins, and there, altering, it sanguifies and is carried to the source. There is discussion about this in *On Nutriment*.

Two interesting words emerge from this passage. First, the useful nutriment as it first passes into the vascular system Aristotle here describes as an ἀναθυμίασις, or 'exhalation', the word he uses for it repeatedly.[22] In the *Meteorologica* he explains that (Passage 8) (*Mete.* 359b28–34)

ἔστι γὰρ δύ' εἴδη τῆς ἀναθυμιάσεως . . . ἡ μὲν ὑγρὰ ἡ δὲ ξηρά· καλεῖται δ' ἡ μὲν ἀτμίς, ἡ δὲ τὸ μὲν ὅλον ἀνώνυμος, τῷ δ' ἐπὶ μέρους ἀνάγκη χρωμένους καθόλου προσαγορεύειν αὐτὴν οἷον καπνόν· ἔστι δ' οὔτε τὸ ὑγρὸν ἄνευ τοῦ ξηροῦ οὔτε τὸ ξηρὸν ἄνευ τοῦ ὑγροῦ, ἀλλὰ πάντα ταῦτα λέγεται κατὰ τὴν ὑπεροχήν.

there are two types of exhalation, the moist and the dry; the former is called vapour, the latter, as a whole, lacks a name, but, using the part for the whole, one must call it a kind of smoke; and it is not possible for the moist to exist without the dry, nor the dry without the moist, but all these [combinations] are spoken of [as moist or dry] according to which predominates.[23]

This characterization suggests that, as it is heated in the process of digestion, the chyle in the intestines emits a steamy and particulate emanation that rises, in accordance with its hot, vaporous and smoky nature, into the veins and thence continues its upward path towards the heart.

The second, potentially more troubling, word is 'sanguifies' (ἐξαιματοῦται). Though it is not at all inconsistent to say that it changes in some way on this next step in its digestive journey, the exhalation from food has absolutely no business turning into blood in the veins before it gets to the heart.[24] Aristotle is consistently and

[21] *Part. an.* 678a1–3: πλῆρες ὂν φλεβῶν πολλῶν καὶ πυκνῶν, αἳ τείνουσιν ἀπὸ τῶν ἐντέρων εἵς τε τὴν μεγάλην φλέβα καὶ τὴν ἀορτήν.

[22] *Part. an.* 672b18; *Insomn.* 462b6; *Juv.* 469b31; *Resp.* 480a10; *Somn. passim*.

[23] Compare *Mete*. 341b7–14, 357b25–7, 369a14–16, 378a19–20. Aristotle's characterization of this digestive substance as an exhalation is further tightened by his likening its movements to those of rain (see Passage 9 above), which is a meteorological condition driven by the evaporation and condensation of these exhalations (*Mete.* 346b32–3, 358a20–6, 359b35–360a17).

[24] Nevertheless, this passage is usually interpreted and/or translated to indicate that blood formation occurs in the vessels as well as in the heart; see, for example, Ogle (n. 4), 203 n. 9; Hett (n. 11), 335; Lanza and Vegetti (n. 4), 1153; Harris (n. 2), 158; and Gallop (n. 11), 75. Indeed, P. Manuli and M. Vegetti, *Cuore, sangue, cervello: biologia e antropologia nel pensiero antico* (Milan, 1977),

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unequivocally clear about the fact that blood originates in the heart and nowhere else. Indeed, in the same treatise, only a few pages after the quote we are considering, he reaffirms: 'the source of **all** the blood, as has been said both here and in other places, is the heart.'[25] The word he uses here, ἐξαιματόειν, becomes the standard word in later medical theory for the manufacture of blood by the liver, hence its typical translation as 'become blood' or 'sanguify', but this is the only surviving attestation of it in Aristotle and indeed in any author before the first century A.D. There appear to me to be three different ways of dealing with this problem. The first is to assume, as some have done, that the verb here should be translated more along the lines of 'take a step in the process of becoming blood' rather than 'actually become blood'.[26] The conjunction with the participle 'changing' (μεταβάλλουσα) does make this tempting, but this is by no means a standard use of the word and, for an apparently newly coined term, is asking the reader to do what is perhaps an unrealistic degree of interpretation. The second possibility is to assume that this passage is the interpolation of a later editor of the text. The next attestation of ἐξαιματόειν after this one is not until Philo Judaeus, the Jewish philosopher living in Alexandria at the turn of the first century A.D.; he uses it in the same way Galen does—to describe the blood-creating capability of the liver.[27] The term appears as well, with the standard later meaning, in a discussion in the Anonymus Londiniensis papyrus of the doctrines of the later Hellenistic author Asclepiades.[28] All this could conspire to suggest that the word was first coined in the flourishing of medical activity in Hellenistic Alexandria and, thus, that a Hellenistic editor of the *Parua Naturalia* is responsible for some entrenched interpolations in this section of the treatise.[29] The third possibility is to doubt that the word carries the same connotation here that it comes to have in later authors. Aristotle could simply be using the prefatory ἐκ- to indicate a complete or intensified degree of the verb αἱματόειν, which was used quite commonly in the fifth and fourth centuries B.C., from history to tragedy to comedy, to mean 'make bloody' or 'stain with blood'.[30] In this model, the passive intensified form used here would likely best be rendered: 'is covered utterly with blood' or 'is drenched in blood'. In other words, as would be consistent with its entrance into the vascular system, the exhalation from the food becomes incorporated into the bloodstream.

Regardless of how precisely one chooses to interpret the passage above, it is quite clear that the exhalation from the food has entered the vascular system and, thus, that

144–5 cite this passage as proof of an early hemocentric theory in Aristotle that was later firmly but incompletely erased by the cardiocentrism of *Parts of Animals*; they cite *Part. an.* 668b8–9 as another example of a trace of it, but that passage refers to the secondary concoction of already concocted blood into residues (in this case sweat) rather than to the concoction of nutriment into blood.

[25] *Somn.* 458a15–16: **παντὸς** δὲ τοῦ αἵματος ἀρχή, ὥσπερ εἴρηται καὶ ἐνταῦθα καὶ ἐν ἄλλοις, ἡ καρδία.

[26] This is the approach of, for example, I.M. Lonie, 'Erasistratus, the Erasistrateans, and Aristotle', *BHM* 38 (1964), 426–43, at 437 and J. Althoff, *Warm und kalt, flüssig und fest bei Aristoteles. Die Elementarqualitäten in den zoologischen Schriften* (Stuttgart, 1992), 90.

[27] Philo, *Spec. leg.* 1.216.

[28] Anon. Lond. 34.46–7. Asclepiades was active in the first century B.C.; the papyrus dates to the first century A.D. (see D. Manetti, *Anonymus Londiniensis. De Medicina* [Berlin, 2011], ix).

[29] Shaw (n. 2), 379–80 is quite enthusiastic about the possibility of discrediting sections of *On Sleep*, citing a rather more cautious Ogle (n. 4), 200 n. 26.

[30] On ἐκ in compounds, see LSJ s.v. C.2: 'to express completion, like our *utterly*'. For the contemporary use of αἱματόειν, see Thuc. 7.84.5; Eur. *Supp.* 77, *Phoen.* 1149, *Bacch.* 1135; Ar. *Pax* 1020; Xen. *Cyr.* 1.4.10.

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it has entered the blood, for which the vessels serve everywhere as containers.[31] From here, the food must make its way to the heart in order to achieve its final concoction, and the heat inherent in the nutritive exhalation appears to facilitate this upward rise. Thus the blood with which the partially digested food particles are now saturated, agitated and heated by this intruding exhalation, will have to **return to the heart** via both the aortic system and the great vein system. Yet, the immediate next step on the journey for this food exhalation that Aristotle describes is not in the heart but in the head.

Aristotle describes the role of the brain in digestion in several different texts.[32] In *Parts of Animals* he introduces the analogy of evaporation leading to rain to explain why the coolness of the brain leads to the production of phlegm and nasal congestion. He says (Passage 9) (*Part. an.* 652b36–653a2, 10–16):

ἀναθυμιωμένης γὰρ διὰ τῶν φλεβῶν ἄνω τῆς τροφῆς τὸ περίττωμα ψυχόμενον διὰ τὴν τοῦ τόπου τούτου δύναμιν ῥεύματα ποιεῖ φλέγματος καὶ ἰχῶρος. . . ποιεῖ δὲ καὶ τὸν ὕπνον. . . τοῦτο τὸ μόριον. . . καταψῦχον γὰρ τὴν **ἀπὸ τῆς τροφῆς τοῦ αἵματος** ἐπίρρυσιν . . . βαρύνει τε τὸν τόπον (διὸ τὴν κεφαλὴν καρηβαροῦσιν οἱ ὑπνώσσοντες) καὶ **κάτω** ποιεῖ τὸ θερμὸν ὑποφεύγειν **μετὰ τοῦ αἵματος**.

after **the food has risen up as an exhalation through the veins**, the residues, cooling down because of the power of this place [the brain], cause discharges of phlegm and ichor . . . And this region also causes sleep . . . for, cooling down the influx of **the blood from the food** . . . it both weighs down its part of the body (wherefore sleepy people have heavy heads) and makes the heat recede **downwards, together with the blood**.

In *On Sleep* he refers to this same event repeatedly, discussing it, at various points, in similar terms. There he tells us that sleep 'comes about from the exhalation attendant on food', which, because of its very nature as an exhalation, is 'necessarily thrust up to a certain point, and then wheels about and changes course, as if in a narrow strait'.[33] Because heat has a tendency to rise, he tells us, the food exhalation—and, presumably, its attendant blood, the substance being here described as 'both liquid and particulate'—goes right up to the head 'through the veins', before it 'sinks downwards' 'upon the primary *aisthētērion*', that is, the heart.[34]

The migratory substance in question here is interchangeably characterized in Passage 9 both as a food-exhalation and as blood, confirming the preceding analysis that the as-yet-unconcocted nutritive matter is travelling in a mobile stream of blood.[35] Indeed, Aristotle says explicitly in *On Sleep* that 'after the influx of food, the blood gets mixed up', indicating clearly that the movement of the nutritive exhalations effects a corresponding movement of blood.[36] Given the arrangement of the vascular system,

[31] *Hist. an.* 520b10–19. Cf. *Hist. an.* 511b11–20; *Part. an.* 654a32–b11; *Gen. an.* 740a22–4.

[32] In addition to the passages given here, there is similar language at *De an.* 444a12–13.

[33] *Somn.* 456b18–22: ἐκ τῆς περὶ τὴν τροφὴν ἀναθυμιάσεως γίγνεται τὸ πάθος τοῦτο· ἀνάγκη γὰρ τὸ ἀναθυμιώμενον μέχρι του ὠθεῖσθαι, εἶτ' ἀντιστρέφειν καὶ μεταβάλλειν καθάπερ εὔριπον.

[34] *Somn.* 456b22–8, particularly translated at 25 (τό τε ὑγρὸν καὶ τὸ σωματῶδες, 'both liquid and particulate') and 27 (ῥέψῃ κάτω, 'sinks downwards'), 457b21 (διὰ τῶν φλεβῶν, 'through the veins'; cf. 457a11–27), 458a27–8 (ἐπὶ τὸ πρῶτον αἰσθητήριον, 'upon the primary *aisthētērion*').

[35] It does not seem plausible that both of these terms might be describing fully concocted blood. Aristotle would not characterize blood as an exhalation; the former is always a liquid, whereas the latter is always a vaporous or smoky substance, often explicitly contrasted with the liquid state. It seems more probable that he is here describing a flow of blood, perhaps made frothy by the addition of the exhalation, rising to the head, where the entire mixture cools and condenses, falling back down as an unqualified, though still not completely concocted, liquid.

[36] *Somn.* 458a21–2: τὸ γίγνεσθαι ἀδιακριτώτερον τὸ αἷμα μετὰ τὴν τῆς τροφῆς προσφοράν.

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this blood-nutriment mixture cannot get to the vessels of the head without going through the heart on the way. Since the nutritive matter that reaches the head continues to be described as an exhalation, rather than as fully blood, we must infer that it traversed the heart in this initial pass without lingering long enough to be fully concocted into blood. Indeed, given the turbulent upward velocity that Aristotle ascribes to it, it is an open question whether any significant quantity of this food-laden blood would have time to get from the two side-chambers, to which the main vessels connect, into the central chamber, which, as I will discuss shortly, seems likely to be the special blood-producing region. Even if some small part of the new food exhalation managed to achieve full concoction on this initial pass, it certainly appears that the majority of it continues, unfinished, straight up to the head.

Once in the head, the blood-food mixture undergoes a change. In Passage 9 above we learned that the cooling power of the brain chills the residues, causing 'discharges of phlegm and ichor'. The parallel discussion in *On Sleep* offers more details: 'the residue-like exhalation is condensed into phlegm, but the nourishing and not unwholesome exhalation, condensed, is carried down.'[37] Given the parallel situations in these two passages, it seems safe to conjecture that the cooling process of the brain causes the phlegmy residues in the food-blood mixture to collect and filter out in a discharge of phlegm. This condensation of the residual material causes the remaining, beneficial, parts of the nutritive exhalation, having been thus filtered of phlegm and themselves 'condensed', to then flow down as a separate discharge of ichor, which Aristotle defines in *History of Animals* as 'unconcocted blood' and in *Parts of Animals* as 'the part of blood that is watery on account of not yet having been concocted or of having decomposed'.[38] Thus the trip to the brain seems to have materially altered the nutritive exhalation in such a way that it is now purer and ready to undergo the final step of concoction in the heart, having, in the process, more effectively homogenized it with the blood that is carrying it—it is no longer an exhalation mixed with blood but is now ichor, a more integrated, albeit unfinished, element of the bloodstream.

After this filtering process in the head, Passage 9 above indicates that the now more fully integrated nutritive matter goes 'downwards with the blood'. Given the vascular arrangement, the only plausible destination for this downward flow, which has now lost its effervescent degree of heat, is the heart, and the passages quoted above from *On Sleep* indeed confirm that it flows to the 'primary *aisthētērion*'. Thus the blood (which has definitionally already been there at least once, at the moment of its formation) and the now-purified food exhalation that it is transporting are making their second trip to the heart on this digestive journey so far.

The very process of digestion and blood creation, then, involves the flow of already created blood into and out of the heart. But even outside this unusually turbulent period, when 'the blood [becomes] mixed up after the intake of food', there seems to be a constant, low-level movement of blood, not-yet-blood and other materials into and out of the heart and up and down the vascular system.[39] First of all, despite its

[37] *Somn.* 458a2–5: ἡ μὲν περιττωματικὴ ἀναθυμίασις εἰς φλέγμα συνίσταται (διὸ καὶ οἱ κατάρροι φαίνονται γιγνόμενοι ἐκ τῆς κεφαλῆς), ἡ δὲ τρόφιμος καὶ μὴ νοσώδης καταφέρεται συνισταμένη.

[38] *Hist. an.* 521b3: γίνεται δὲ πεττομένων ἐξ ἰχώρων μὲν αἷμα, ἐξ αἵματος δὲ πιμελή . . . ἰχὼρ δ' ἐστὶν ἄπεπτον αἷμα, ἢ τῷ μήπω πεπέφθαι ἢ τῷ διωρῶσθαι; *Part. an.* 651a17–18: ἰχὼρ δ' ἐστὶ τὸ ὑδατῶδες τοῦ αἵματος διὰ τὸ μήπω πεπέφθαι ἢ διεφθάρθαι.

[39] *Somn.* 458a21–2: διὰ δὲ τὸ γίγνεσθαι ἀδιακριτώτερον τὸ αἷμα μετὰ τὴν τῆς τροφῆς προσφορὰν ὕπνος γίγνεται.

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immediate return to the heart, all of the ichor distilled by the brain does not achieve final concoction on that trip. The ichor, as part of the blood, appears throughout the body. Children, for example, who crop up throughout the corpus as creatures who eat excessively and whose heads are full of food and thus disproportionately large and heavy, have blood throughout their bodies that is especially 'ichor-y' and abundant.[40] In pathological situations, where a person's blood has become 'excessively liquid' and 'ichor-y', it is even able to exit the pores in a 'blood-like sweat'.[41]

The fact that this not-completely-concocted proto-blood is able to travel in the body comingled with the completed blood is one way to explain some otherwise puzzling passages in which other organs take part in digestion and in the concoction of blood. In *On Youth and Old Age*, Aristotle tells us that 'all the parts of the body work on and concoct the food with their natural heat, but most of all the most authoritative part [the heart]'.[42] In *Parts of Animals* he specifically singles out the digestive roles of the liver and the spleen, which, again, because of the arrangement of the vascular system are not in a position that could be logically expected to receive all of the initially absorbed exhalation prior to its arrival in the heart.[43] Further, it is because they are full of blood, and therefore hot, that they are able to assist in concoction and this blood, as in all organs except the heart, must be contained in the vessels, which, in this model, is also the only plausible location for the food that they are working on—indicating, once again, that the incompletely concocted food (which must eventually go to the heart) is contained in blood (which must eventually return there to deliver it).[44]

Blood, then, in the final step of digestion (for this particular batch of food that we are following, at least) will have to go *to* the heart once again in order to facilitate the final sanguification of the proto-blood it is transporting. Nor is this a hypothetically necessary but unsubstantiated claim. Despite the strong words in *Parts of Animals* with which we began, Aristotle suggests influx into the heart as a commonplace in several passages

[40] *Hist. an.* 521a33. Indeed, in animals with insufficient heat to effect fully sanguifing concoction, the ichor simply takes over throughout the system as counterpart of the blood (cf. *Hist. an.* 489a23, 511b4).

[41] *Hist. an.* 521a13: ἐξυγραινομένου δὲ λίαν νοσοῦσιν· γίνεται γὰρ ἰχωροειδές, καὶ διορροῦται οὕτως ὥστε ἤδη τινὲς ἵδισαν αἱματώδη ἱδρῶτα. Compare to *Hist. an.* 586b32, 630a6, 632a18, where ichor runs out of wounds.

[42] *Juv.* 469b6–13: ἐργάζεται γὰρ καὶ πέττει τῷ φυσικῷ θερμῷ τὴν τροφὴν πάντα, μάλιστα δὲ τὸ κυριώτατον.

[43] *Part. an.* 670a19–21. Indeed, the descriptions at *Hist. an.* 496b29–33 and, depending on how it is interpreted (see n. 16 above), possibly also the *Part. an.* passage immediately preceding this one emphasize that the liver and spleen are not connected to the aorta at all, meaning that they would miss out on half of the nutritive exhalations drawn from the intestines. Boylan (n. 4) (cf. M. Boylan, *The Origins of Ancient Greek Science. Blood—A Philosophical Study* [New York and London, 2015]) repeatedly and confidently asserts that the liver and spleen are the next step in the digestive process after the food exits the digestive tract, but there is absolutely no textual support for this claim (as, indeed, he largely concedes in two footnotes: [n. 4], 103 n. 31 and 110 n. 40). Beyond this lack of positive evidence, the description of the vascular system, as I have argued, tends to prohibit such an arrangement. Boylan's only plausible evidence in his assertion that the spleen is prior to the heart on the path of digestion is the passage at *Part. an.* 670b4–6, where Aristotle describes how the spleen 'draws to itself the watery residue out of the stomach and, being bloody, is able to concoct it' (ὁ γὰρ σπλὴν ἀντισπᾷ ἐκ τῆς κοιλίας τὰς ἰκμάδας τὰς περιττευούσας, καὶ δύναται συμπέττειν αἱματώδης ὤν); this, however, is a description of the spleen receiving non-nutritive residue in direct contrast to nutritive exhalation. The concoction here is not a digestive but a residual concoction.

[44] An alternative way of dealing with this statement is to assume that the liver and spleen aid in concoction only indirectly, by means of making the stomach and intestines hotter, as seems to be the case for the omentum (*Part. an.* 677b30–4).

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across the corpus. In *Parts of Animals*, for example, he mentions that pain, pleasure and sensation proceed from the periphery to the heart, and indicates that it is the blood that facilitates this movement.[45] Most emphatically, he implies in *On Sleep* that the heart 'receives' blood from the two main vessels and, in *On Dreams*, says explicitly that during sleep 'the majority of the blood goes down to the source'.[46]

The obvious next question is: what precisely happens in the heart? How and where does the final change take place and how can the seemingly simultaneous inflow and outflow of blood and nutrition be reconciled? As to the how and where of the change, the descriptions of the heart in both *Parts of Animals* and *On Sleep* indicate that the central chamber is the source within the source—it is not a large leap to infer that its special balance of heat and its markedly important place in Aristotle's theory of locational hierarchy allow it to act on the nutriment in the special way required to produce blood. As to the traffic problem posed by influx and efflux along the same channels, the fact that the nutrition is mixed in with the blood as an integrated part of the bloodstream obviates the need for physiologically improbable situations like the situation Boylan posits with his suggestion that 'perhaps the [*uena caua*] has two channels, or, more probably, that blood and nourishment are mutually insoluble, so that, like oil and water, they coexist without mixing'—a theory which has to do the arduous work of allowing these two insoluble liquids to somehow be flowing simultaneously through each other in opposite directions.[47] Rather it seems more probable to imagine a uniform flow into and out of the heart which consists of both fully and partially concocted blood, with the unfinished blood gradually achieving the final step of concoction on its various passes through the heart.[48]

The closest Aristotle comes to discussing the mechanics of this process is in the treatise *On Respiration*. Here he is describing the difference between 'pulsation' (σφύξις), which accounts for the perceived heartbeat, and 'respiration' (ἀναπνοή), which is a movement of the heart that causes the inflation of the thoracic cavity and thus the inhalation of air into the resulting vacuum in the lungs. Pulsation he particularly equates to the pulsating pain of a pathological swelling or to the boiling of water. In the former, the contained liquid cannot escape and eventually boils down and putrefies; in the latter, the boiling water simply overflows its container. In the heart (Passage 10) (*Resp.* 480a2–7),

[45] *Part. an.* 666a11–13: ἔτι δ' αἱ κινήσεις τῶν ἡδέων καὶ τῶν λυπηρῶν καὶ ὅλως πάσης αἰσθήσεως ἐντεῦθεν ἀρχόμεναι φαίνονται καὶ πρὸς ταύτην [i.e. τὴν καρδίαν] περαίνουσαι; 653b5–8: τὸ γὰρ ἐν τῇ καρδίᾳ θερμὸν καὶ ἡ ἀρχὴ συμπαθέστατόν ἐστι καὶ ταχεῖαν ποιεῖται τὴν αἴσθησιν μεταβάλλοντός τι καὶ πάσχοντος τοῦ περὶ τὸν ἐγκέφαλον αἵματος.

[46] *Somn.* 458a17–19: ἐκείνων δ' ἑκατέρα δέχεται ἐξ ἑκατέρας τῆς φλεβός, τῆς τε μεγάλης καλουμένης καὶ τῆς ἀορτῆς· ἐν δὲ τῇ μέσῃ γίγνεται ἡ διάκρισις; Lloyd (n. 11), 243 n. 81 briefly admits the troubling implications of this quote in contrast to our original passage from *Part. an.* 666a6–8; Shaw (n. 2) also signals it as potentially problematic, but dismisses it as 'possibly spurious' (at 355 n. 1) and asserts that, at the very least, there is 'no possible way to align it with the general cardiology to be found in other Aristotelian works' (at 388); Althoff (n. 26), 90 suggests that it is not blood that is in question here but nutritive matter which has almost become blood, though he acknowledges that this interpretation leaves him with an unresolved traffic jam as the new blood leaves the heart (cf. Zierlein [n. 4], 46 n. 7 and Oser-Grote [n. 4], 125). *Insomn.* 461b11–13: ὅταν γὰρ καθεύδῃ, κατιόντος τοῦ πλείστου αἵματος ἐπὶ τὴν ἀρχὴν συγκατέρχονται αἱ ἐνοῦσαι κινήσεις, αἱ μὲν δυνάμει αἱ δὲ ἐνεργείᾳ.

[47] Boylan (n. 4), 116.

[48] One might imagine the vascular system as a pot of custard cooking on a stove. At intervals, the chef might add some new uncooked milk and egg; this new raw addition would flow through and with the already cooked custard as it was stirred, only gradually achieving the temperature required to be fully cooked as it passed close to the heat source.

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ἡ τοῦ ἀεὶ προσιόντος ἐκ τῆς τροφῆς ὑγροῦ διὰ τῆς θερμότητος ὄγκωσις ποιεῖ σφυγμόν, αἰρομένη πρὸς τὸν ἔσχατον χιτῶνα τῆς καρδίας. καὶ τοῦτ' ἀεὶ γίνεται συνεχῶς· ἐπιρρεῖ γὰρ ἀεὶ τὸ ὑγρὸν συνεχῶς, ἐξ οὗ γίνεται ἡ τοῦ αἵματος φύσις. πρῶτον γὰρ ἐν τῇ καρδίᾳ δημιουργεῖται.

the heat-induced swelling of the constantly in-flowing moisture from the nutriment causes pulsation, as it rises towards the outer layer of the heart. And this is always happening continuously. For the liquid from which the nature of blood comes about always flows continuously in. For it [blood] is first created in the heart.

This is coupled with the comparatively slower process (matched to observable respiratory rate rather than heart rate) of respiration, which (Passage 11) (*Resp.* 480a16–20)

[ἡ δ' ἀναπνοὴ] γίνεται αὐξανομένου τοῦ θερμοῦ ἐν ᾧ ἡ ἀρχὴ ἡ θρεπτική. καθάπερ γὰρ καὶ τἆλλα δεῖται τροφῆς, κἀκεῖνο, καὶ τῶν ἄλλων μᾶλλον· καὶ γὰρ τοῖς ἄλλοις ἐκεῖνο τῆς τροφῆς αἴτιόν ἐστιν. ἀνάγκη δὴ πλέον γινόμενον αἴρειν τὸ ὄργανον.

comes about with the increasing of the heat in which the nutritive source resides. For just as all the other parts also require nourishment, so does it [the heart], and more than the others. For this is the cause of nourishment for the others. And it is necessary that the organ swell as this [nourishment] becomes more abundant.

The swelling of the heart that causes respiration is cooled (and therefore deflated) by the cool air pulled in through the opening of the pulmonary cavities, thus causing cardiac contraction, which in turn mechanically leads to exhalation.

The differences between these two motions of the heart are puzzling, given that they seem to result from the same cause yet proceed at markedly different rates. The best way to imagine it is perhaps that the influx of food-laden blood expands under the influence of the heat of the heart, pushing out the heart in a pulsation. Though the heart is not open like a pot of boiling water, unlike a tumor, it does have egresses, namely the great vein and the aorta. One can imagine an estuary-like situation there: as the pressure of the cardiac contents builds up, it expands the walls of the heart and some of it manages to overcome the influx of fresh food-laden blood through these openings and create a countervailing rush of exiting, fully processed blood. Some of this new blood would then be brought right back in with the 'ichor-y' or food-laden blood, but, depending on how recently the person has eaten and where the prevailing movements in the bloodstream are heading, some of it might get swept up to the head or fall down to the lower organs. These releases of blood, however, can only account for small and temporary relief and the heat, the liquid and the hot evaporations in the heart continue to expand, until, at last, the respiratory movement is achieved, cooling down the boiling turmoil and dramatically lessening its volume.

Within these violent and countervailing movements, the central chamber of the heart maintains an incongruous peace. As we saw in Passage 4 above, Aristotle describes it as 'calm' and containing blood that is 'pure and intermediate as to quantity and heat'. This is the place in the body where the heat—that vital quality of life in the Aristotelian model—is at its most perfect degree. This is also very likely the site of the primary *aisthētērion*, where the soul interacts most intimately with the body. These two qualities allow for the perfect conditions within which to convert the heavily purified and concocted nutritive matter mixed in with the blood into actual blood itself. Aristotle offers no clear or definite description of this process. My own suspicion is that we can lean fairly hard on the boiling simile in *On Respiration*—'[pulsation] is similar

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to boiling; for boiling comes about when moisture has been aerated by heat'.[49] It does not seem out of the question that the final concoction of blood from proto-blood involves an addition of the mysterious but powerful inborn *pneuma*, which often seems to operate within it.[50]

Once the blood, whether newly or previously finalized, manages to escape the tumultuous back-and-forth of the heart, it is free to wander through the vascular system. What propels it on this journey is an open question. Aristotle seems largely uninterested in staking out a position in what will, not long after his death, become one of the more hotly contested debates in the field. It is certainly not out of the question that he thought that the contraction of the heart offers enough propulsion to send the blood far out into the vascular system, much as the correlated contraction of the lungs propels the air out in exhalation. It is also not impossible that the *pneuma* with which the blood is imbued has some sort of motive role, though Aristotle may seem to suggest elsewhere that this is not the case.[51] The most likely candidate seems to me to be the heat.[52] As we saw already in the earlier stages of digestion, the heat of the nutritive exhalation drives it up to the top of the body, where, like evaporated water forming rain clouds, it cools, becomes heavy and falls back downwards. A similarly heat- and weight-based framework might be enough to drive the remaining periods of blood flow. Indeed, we are told in *On Sleep* that, after digestion is resolved, the pure, thin blood goes to the upper parts of the body, whereas the heavier, turbid blood goes down.[53]

FLESH AND THE RESIDUES: THE CASE OF SEMEN

The final fate of the blood is to become flesh or a residue.[54] Viewed from a chronological standpoint, there are two different kinds of residue.[55] The first are

[49] *Resp.* 479b31–3: ἔστι δ' ὅμοιον ζέσει τοῦτο τὸ πάθος· ἡ γὰρ ζέσις γίνεται πνευματουμένου τοῦ ὑγροῦ ὑπὸ τοῦ θερμοῦ.

[50] A.L. Peck, *Aristotle Generation of Animals* (Cambridge, MA, 1963), lxiv, 592–3; Harris (n. 2), 136–7 (citing Peck); and Boylan (n. 43), 56, 64–5 are also sympathetic to this view; G. Freudenthal, *Aristotle's Theory of Material Substance: Heat and Pneuma, Form and Soul* (Oxford, 1995), 122 stops short of suggesting that the moment of pneumatization is equivalent to that of blood formation, but his theory is certainly consistent with it.

[51] He says at *Gen. an.* 737b30 that 'each [residue] is borne to its appropriate place without the *pneuma* compelling it nor any other such cause forcing it' (φέρεται γὰρ ἕκαστον εἰς τὸν οἰκεῖον τόπον οὐθὲν ἀποβιαζομένου τοῦ πνεύματος οὐδ' ἄλλης αἰτίας τοιαύτης ἀναγκαζούσης); Boylan (n. 4), 117 argues that this discussion of the motion of residues is not applicable to blood precisely because blood can be differentiated from residues in light of its pneumatization—thus suggesting that blood *is* compelled by *pneuma*. However, given that this passage occurs in the context of discussing the specific residue semen, which is formed from fully concocted blood and is most pointedly endowed with *pneuma*, I am hesitant to put too much faith into that line of reasoning, neat though it is.

[52] Freudenthal (n. 50), 128–30 similarly suggests that it is the *pneuma* inherent in the blood that contains the vital heat and is thus naturally subject to upward motion.

[53] *Somn.* 458a13–15: ἔστι δὲ λεπτότατον μὲν αἷμα καὶ καθαρώτατον τὸ ἐν τῇ κεφαλῇ, παχύτατον δὲ καὶ θολερώτατον τὸ ἐν τοῖς κάτω μέρεσιν.

[54] For the transformation of blood into flesh and other parts of the body, see *Part. an.* 668a1–33; *Gen. an.* 743a1–28, 744b12–28; and *Gen. corr.* 322a5–16.

[55] Aristotle distinguishes between 'useful' and 'useless' residues at *Gen. an.* 735a4–8, but these categories do not quite map on to the chronological flow of digestion that I am attempting to capture here.

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those which are removed prior to blood formation—these are the elements of the food that were unsuited to be assimilated to the animal's body, including feces, urine, phlegm and bile.[56] The second group of residues are created from excess blood—the result of eating more food than is strictly required for the maintenance of the body. These include hard fat, soft fat (suet), bone marrow, breast milk, menstrual blood and semen.[57] This latter category opens the window for surplus blood to linger in the vascular system, allowing it to conduct the nutritive matter in the various ways we have already considered. Some of these post-blood residues, especially fat and bone marrow, might reasonably be created at the end of the line: once it is clear that the organ or body part to which the blood has arrived has consumed enough blood to sustain itself, the remainder gets further concocted on the spot.[58] The case of semen in particular, however, suggests a wide-ranging mobility for this excess blood.

Semen, to reiterate, is a residue formed by the further concoction of excess blood.[59] In viviparous creatures, at any rate, it is created on demand during the act of copulation.[60] Aristotle is quick to deny that semen is drawn from all parts of the body—indeed, he spends a considerable portion of *Generation of Animals* rebutting the theory of pangenesis—but naming blood as the material from which semen is made is appealing precisely because blood is potentially all parts of the body. Thus semen retains blood's capacity to assimilate to any part of the parent's body, allowing for the generation of all the various parts of the fetus as well as the resemblance of the offspring to the parents.[61] Like the other natural residues, semen has a special location in which it collects, namely the testicles; however, the amount of blood that collects in the testicles to be further concocted into semen appears to be entirely dependent on the needs of the rest of the body.[62] If the diet of an animal results in too much blood being converted into fat, it has less available for semen and becomes increasingly infertile; if an animal is extremely large, it requires a great deal of nutriment to sustain itself and thus has very little leftover to turn into semen; if the animal is growing rapidly, it likewise needs to allocate all of its nutriment to its parts rather than to generation.[63] In contrast, the weakness that the animal feels immediately after the creation and release of semen—a weakness that he elsewhere says is felt not just in the generative organs but throughout the whole body—is 'manifest' and is equivalent to and results from the same cause as the weakness experienced at the loss of too much blood: the animal has been deprived of nutriment.[64] In short, the amount of blood available to become semen at any given time and the amount of blood used in all the other parts of the body seem to be directly interrelated, suggesting that the body has the ability to naturally reallocate excess blood as needed, in turn requiring that the blood move in ways other than a simple radiation out from the heart.

[56] *Part. an.* 677a12–15; *Gen. an.* 725a14–18.
[57] *Part. an.* 651a21–4, 651b20–35; *Gen. an.* 726b2–5, 727a2–4, 777a8–9.
[58] This is what seems to happen with the kidneys (*Part. an.* 672a1–13) and the omentum (*Part. an.* 677b25–8).
[59] *Gen. an.* 725a11–21, 726b2–12, 726b14–15.
[60] *Gen. an.* 718a6–7.
[61] *Gen. an.* 725a24–7, 726b3–15.
[62] On the localized collection of residues, see *Gen. an.* 725a34–b4.
[63] Fat: *Gen. an.* 726a3–7; *Part. an.* 651b12–17; large animals: *Gen. an.* 725a32–4; growth: *Gen. an.* 725b22–5.
[64] On the link between post-coital exhaustion and blood, see *Gen. an.* 725b7–9 and 726b12–13; for the full-bodied nature of the exhaustion, see *Gen. an.* 721b15–18.

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CONCLUSION

It is dangerous to take Aristotle too closely at his word in the passage from *Parts of Animals* with which I began. His statement that 'blood is conducted out of the heart and into the veins, not from elsewhere into the heart' is entirely about the origin of blood, not about its subsequent behaviour. Nutriment can only achieve full blood status in the heart, thus blood does not originate elsewhere and then go to the heart. This very claim, however, necessitates the various digestive peregrinations outlined here and ensures that, once it has been created, the blood travels widely and in many different directions in the vascular system, including repeated return trips through the heart. In short, Aristotle does not describe the simplistic anti-circulatory system that is so often ascribed to him. Rather he presents a fully functional and coherent system of blood flow, consistent with his understanding of human anatomy and physiology, positional hierarchy, and cardiocentrism. There is sufficient evidence to allow us to understand it on its own terms, without reference to any of the theories that post-date it.

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