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DEMOCRITUS' OPHTHALMOLOGY*

Over the last sixty years a series of insightful studies[1] has confronted the difficulties presented by the reports of Democritus' theory of vision, but no one has yet examined the Theophrastean report of Democritus' physiology of the eye to improve our understanding of how the image enters the perceiver.

Our only sources for Democritus' description of the eye are Peripatetic.[2] Aristotle (*Sens*. 438a5–10) agrees with Democritus' general conclusion that the eye is water (ὕδωρ), but criticizes him for saying that vision results from the image (τὴν ἔμφασιν) reflected in the eye, arguing that this is an occurrence of mere reflection (ἀνάκλασις) that arises because the eye is smooth (λεῖον). But for Democritus, the ἔμφασις is not a typical reflection; as the verb ἐμφαίνεται implies, it is a case of the visible object literally being 'imaged in' the eye,[3] a specialized organ which transmits these images to the observer's reasoning faculty.[4] Theophrastus' reports in *De sensibus* concerning his predecessors' theories of vision are far more detailed than his teacher's. This is particularly the case with Democritus (*Sens*. 50.4–11) and Empedocles (*Sens*. 7), but even the more elliptical summaries of Plato (*Sens*. 5), Alcmaeon (*Sens*. 26) and Diogenes (*Sens*. 42) preserve physiological details. In light of such similarities, G.E.R. Lloyd doubts that Democritus' ideas were

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[1] K. von Fritz, 'Democritus' theory of vision', in E.A. Underwood (ed.), *Science, Medicine and History: Essays on the Evolution of Scientific Thought and Medical Practice written in honour of Charles Singer* (Oxford, 1953), 83–99; W.K.C. Guthrie, *A History of Greek Philosophy Vol. 2: The Presocratic Tradition from Parmenides to Democritus* (Cambridge, 1965), 441–4; R.W. Baldes, 'Democritus on visual perception: two theories or one?', *Phronesis* 20 (1975), 93–105; id., 'Democritus on the nature and perception of "black" and "white"', *Phronesis* 23 (1978), 87–100; W. Burkert, 'Air-imprints or eidola: Democritus' aetiology of vision', *ICS* 2 (1977), 97–109; M.M. Sassi, *Le teorie della percezione in Democrito* (Florence 1978); I. Avotins, 'Alexander of Aphrodisias on vision in the atomists', *CQ* 30 (1980), 429–54; D. O'Brien, 'Théories atomistes de la vision: Démocrite et le problème de la fourmi céleste', in L. Benakis (ed.), *Proceedings of the First International Congress on Democritus* (Xanthi, 1984), 27–57; J. Salem, *Démocrite: Grains de poussière dans un rayon de soleil* (Paris, 1996), 129–32; P.-M. Morel, *Démocrite et la recherche des causes* (Paris, 1996), 224–40; C.C.W. Taylor, *The Atomists: Leucippus and Democritus* (Toronto, 1999), 208–11; K. Rudolph, 'Democritus' perspectival theory of vision', *JHS* 131 (2011), 67–84.

[2] Aristotle and Theophrastus indicate that Democritus' theory involves εἴδωλα entering the eye. DK 68B123 preserves Democritus' term δείκελον for this 'effluence similar in kind to the object' from which it flows. Cf. DK 67A29, 68A1 (= Diog. Laert. 9.44) and 68A31.

[3] Even in Peripatetic texts ἔμφασις is used of appearances, such as colours in mist, the way colours mix, or impressions in dreams. Cf. Arist. *Mete*. 3.373a32–b34, 3.374a17–18, 3.377b14–26; [*Col*.] 792a5; *Div. somn*. 464b5–18a. R. Janko, *Aristotle on Comedy: Towards a Reconstruction of Poetics II* (Berkeley, 1984), 202–3 suggests that ἔμφασις originally connotes appearances in need of interpretation. If true, it is unsurprising that Democritus, who considers the senses 'bastard' sources of knowledge (DK 68B11), would highlight this ambiguity.

[4] Or, as Theophrastus asserts (*Sens*. 54.6–8), to the 'rest of the body'.

based on direct observation, suggesting that his reports of the eye and the ear (*Sens*. 56) are applications of a 'general model to both these senses at some cost to the accuracy of his description of either'.[5] However, evidence for Democritus' knowledge of physiology is more substantial than Lloyd suggests. In fact, more than any other optical account in the *De sensibus*, Democritus' reported description of the eye resembles what little Hippocratic material survives on the topic.

Democritus' affinity with contemporary medical writers can be seen in a number of ways. Among the works attributed to Democritus by Thrasyllus are three books on the *Causes of Animals*, as well as possibly medicine-related works on *Prognosis, On Diet or Dietetics* and *Medical Opinion*. The pseudo-Hippocratic letters tell an undoubtedly fanciful story of Hippocrates who, summoned to treat the 'mad' Democritus, finds him in the garden calmly dissecting animals, fully in control of his mental faculties.[6] Stylistically and conceptually the letters resemble the philosophy and science of the Hellenistic period, but they demonstrate an awareness of Democritus' interest in animal physiology and suggest that his interest in medical topics and physiology was well known in the Hellenistic period.[7]

With Democritus' interest in physiology in mind, I now turn to Theophrastus' report at *De sensibus* 50.4–11:

> ἔπειτα τοῦτον
> στερεὸν ὄντα καὶ ἀλλόχρων ἐμφαίνεσθαι τοῖς ὄμμασιν ὑγροῖς. καὶ τὸ μὲν
> πυκνὸν οὐ δέχεσθαι, τὸ δὲ ὑγρὸν διιέναι. (b) διὸ καὶ τοὺς ὑγροὺς τῶν σκληρῶν
> ὀφθαλμῶν ἀμείνους εἶναι πρὸς τὸ ὁρᾶν, εἰ ὁ μὲν ἔξω χιτὼν ὡς λεπτότατος
> καὶ πυκνότατος εἴη, τὰ δ' ἐντὸς ὡς μάλιστα σομφὰ καὶ κενὰ πυκνῆς καὶ
> ἰσχυρᾶς σαρκός, ἔτι δὲ ἰκμάδος παχείας τε καὶ λιπαρᾶς, καὶ αἱ φλέβες
> κατὰ τοὺς ὀφθαλμοὺς εὐθεῖαι καὶ ἄνικμοι, ὡς ὁμοιοσχημονεῖν τοῖς
> ἀποτυπουμένοις. τὰ γὰρ ὁμόφυλα μάλιστα ἕκαστον γνωρίζειν.

Then this [*sc*. air], being both solid and of a different colour, becomes imaged in the eyes, which are moist. The dense cannot receive it, while the moist lets it pass through. Which is why, also, moist eyes are better than hard eyes for seeing, if the outer coat is as fine and dense as possible, the insides as spongy as possible and without dense and strong flesh, or further, thick, greasy liquid, and the ducts from the eyes are straight and moistureless, so that they have a shape similar to the air impressions; for each thing most readily recognises that which is of a kindred type.

The details of *De sensibus* 50 suggest that Theophrastus follows Democritus closely. The combination of familiar Hippocratic references to the outer coat and eye ducts and the description of the internal structure of good and bad eyes suggest that, even if Democritus did not dissect, he had access to technical treatises or first-hand

[5] G.E.R. Lloyd, 'Alcmaeon and the early history of dissection', *ZWG* 59 (1975), 113–47, at 132.

[6] W.D. Smith, *Hippocrates: Pseudepigraphic Writings* (Leiden, 1990), 17.2.5–8, 12–17, and pp. 20–32.

[7] E.M. Craik (ed. and tr.), *Two Hippocratic Treatises:* On Sight *and* On Anatomy (Leiden and Boston, 2006), 168 surmises that the short medical treatise *On Anatomy* is derived from a Democritean text. See DK 68A145 and 68A148 for Democritus' description of the formation of the embryo and the invisibly minute viscera of bloodless animals. See also DK 68A151–5. See further L. Perilli, 'Democritus, zoology and the physicians', in A. Brancacci and P.-M. Morel (edd.), *Democritus: Science, the Arts, and the Care of the Soul* (Leiden, 2007), 143–79.

accounts of the subject.[8] The contemporary Hippocratic *Places in Man* and *On Sight*, both thought to date to the late fifth or early fourth century B.C., include descriptions of the eye that share features with Theophrastus' report.

The account begins with the statement that a ὑγρός eye is better for seeing than a σκληρός eye. These terms cover a broad semantic range; ὑγρός can mean both 'soft' and 'fluid' as well as 'moist', and σκληρός can signify 'dry' and 'hard'. The double functionality of the terms makes them good descriptors of what happens in the eye. Democritus' pronouncement that a 'moist' eye is better for seeing than a 'dry' one is compatible with what we find in the medical treatises, since common ocular ailments including conjunctivitis and trachoma result in dry eye.[9] However, the medical texts most commonly describe such complaints as ξηρός; σκληρός more often indicates firmness or harshness.[10] If firmness is meant by σκληρός in our passage, Democritus may instead be referring to the difference between soft mammal eyes and hard crustacean or insect eyes. His interest in the latter is well attested[11] and he is concerned with differences between human and animal perceptions (*Sens*. 64). Aristotle, whose dissections of crustaceans are remarkably detailed and accurate, makes a similar categorization, which suggests that Democritus' twofold classification is not solely theoretical.[12]

After describing the best characteristics for sight, Democritus turns to the eye's membrane, which he describes as λεπτότατος καὶ πυκνότατος. Most scholars have rejected the manuscript reading. Taylor omits ὡς … πυκνότατος with von Fritz, arguing that it contradicts both the fineness of the eye's membrane and Theophrastus' assertion that dense objects cannot receive an image.[13] Baldes, translating 'thin and dense', suggests that the air impression enters the dense coat through ducts running from it through the eye, thus admitting similar atomic structures and screening out the dissimilar.[14] Baldes' reading strains the text, since there is no hint that the ducts pass through the outer membrane. Burkert argues that πυκνότατος can 'hardly be right' and emends to στιλπνότατος, citing evi-

[8] Treatments for eye injuries are also mentioned in Hippoc. *VC* 13.6–7 (III.230L) and *Epid.* 5.49 (V.236L). DK 24A10 credits Alcmaeon with dissection and even surgery on the eye, although Lloyd (n.5), 123–5 argues that the evidence only allows one to say that Alcmaeon used the knife to examine the structure of the nerves connecting the eye and the brain.

[9] Hippoc. *Loc. hom.* 2.8–20 (VI.278L) suggests that the liquid in the eye is responsible for the imaging (ἐμφαίνεται) that takes place there, and that if it dries up, blindness results. The moisture of the eye may be special in this respect, that it does not produce the normal reflection one finds in water or mirrors; rather, it provides the type of reflection necessary for vision. Cf. Hippoc. *Carn.* 17.1–21 (VIII.604–6L); *Aer*. 10.30, 34, 64 (II.46–8L); *Aph.* 3.12.6–7, 14 (IV.490–2L).

[10] For σκληρός as 'hard' see Hippoc. *VM* 18 (I.614L), 22 (I.630L). *Aer.* 4 (II.18L), 7 (II.26L) provides evidence for both meanings: 'hard' of organs and 'harsh' of water.

[11] See DK 68A148 (Arist. *Part. an.* 3.665a30–33 on bloodless animals) and DK 68A150 (Arist. *Hist. an.* 9.623a30–3 on spiders).

[12] Aristotle (*Hist. an.* 4.526a9; *Part. an.* 2.658a17) and Theophrastus (*Sens*. 36.6) use the adjective σκληρόφθαλμος to differentiate 'hard-eyed' animals, such as crayfish and crabs, from the 'moist-eyed', and Aristotle (*De an.* 2.421a13) mentions that hard-eyed animals have difficulty perceiving colour in order to substantiate the argument that moist eyes are better for seeing.

[13] Taylor (n. 1), 108 following von Fritz (n. 1).

[14] Baldes (n. 1 [1978]), 88–9. Nothing in the *DS* suggests that ducts are present on the eye surface. If they had been, surely Theophrastus would mention the similarity between this and Empedocles' theory.

dence from Alcmaeon, Anaxagoras and Democritus' description of white for the correspondence between transparency and vision.[15]

Two less extreme interpretative options may resolve this ostensible contradiction. The first is to posit two membranes in Democritus' original theory, one fine, the other dense. The elision of a second membrane could have occurred during the transmission of our manuscripts or even while Theophrastus composed the *De sensibus*, particularly if he were using an epitome. The author of *Places in Man* knew of the eye's multiple membranes,[16] and describes them as more dense (παχυτέρη), more fine (λεπτοτέρη) and fine (λεπτή).[17] Therefore, Democritus could quite possibly have known of these membranes, even if he did not dissect an eye himself.

Without definitive evidence, however, the second and more reasonable explanation, and one that seems to have been strangely overlooked, is that Democritus refers to the membrane as λεπτότατος καὶ πυκνότατος because it is 'fine', that is, transparent, and 'compact', that is, resistant to tearing.[18] This brings the description in line with similar accounts for Anaxagoras and Alcmaeon without requiring a textual change. It also accurately describes the anterior sclera, which is marked by both transparency and strength.

Theophrastus then turns to the interior of the eye, reporting that it is 'as spongy as possible and without dense and strong flesh, or further, thick greasy liquid'. If Democritus is alluding to the vitreous chamber with its viscous fluid that occupies the majority of the globe that makes up the eye, it is obvious that he had no knowledge from dissection and we must assume that he is, as Lloyd suggests, applying a general method of explanation to the specific components of the eye. However, if we assume that Democritus here refers to the other interior portions (note the plural: τὰ δ' ἐντὸς, line 8) of the eye, namely the iris, trabecular meshwork and ciliary body, 'spongy' (σομφός) seems to be a fairly good, albeit general, description.[19] None of these structures in the eye is dense or strong, and the aqueous humour has a noticeably thinner consistency than the vitreous humour, which is aptly described as a thick, greasy liquid. Democritus' account of what these functional interior portions are *not* serves to differentiate it from the larger vitreous chamber. Such details are not solely accessible through dissection, since the striations of the iris are visible when the eye is examined up close. However, σομφός itself is an odd word, and although it covers a similar semantic range to

[15] Burkert (n. 1), 101 n. 23. Anaxagoras says that the membrane is fine and clear (*Sens*. 37.8–9), and Alcmaeon suggests that the eye is gleaming and transparent (*Sens*. 26.1–3). The comparison with Democritus' description of white is suspect because *Sens*. 73 is a general statement about the nature of white objects, not the eye.

[16] Hippoc. *Loc. hom*. 2.3 (VI.278–80L.). Cf. Hippoc. *Carn*. 17 (VIII.604–6L.) and [Gal.], *Inst. med.* 14.711 (Kühn), who reports that Hippocrates had identified two ocular membranes; see also E.M. Craik, *Hippocrates' Places in Man* (Oxford, 1998), 33.

[17] Craik (n. 7), 105 suggests that these three coats correspond to the sclerotic membrane (παχυτέρη), the choroid (λεπτοτέρη) and the retina (λεπτή), but cf. Lloyd (n. 5), 135.

[18] LSJ s.v. πυκνός.

[19] As comparison with his treatment of Plato's *Timaeus* reveals, Theophrastus tends to truncate reports of complex details, which may account for the condensed description of the interior of the eye. See A.A. Long, 'Theophrastus' *De Sensibus* on Plato', in K.A. Algra, P.W. van der Horst and D.T. Runia (edd.), *Polyhistor: Studies in the History and Historiography of Ancient Philosophy Presented to Jaap Mansfeld on his Sixtieth Birthday, Philosophia Antiqua* (Leiden, 1996), 345–62; K.C. Rudolph, 'Reading Theophrastus: a reconstruction of Democritus' physics of perception' (Diss. University of Cambridge, 2009), 4–32.

the more common χαῦνος, the former is more often used to describe soft-textured objects (such as the tongue, breasts, lungs or nose) and the latter to describe hard or loose-textured objects (such as pumice, wood or bone).[20] This suggests that Democritus' knowledge of the interior portions of the eye comes from the kind of close observation and analysis obtained through dissection or the treatment of eye injuries. In any case, the description in this passage is no mere application of a general mode of explanation to the visual organ.

Finally, Democritus describes the φλέβες of the eyes. These are straight and moistureless (ἄνικμος) ducts that 'have a shape similar to the air impressions'. Assuming that Democritus is actually describing the physiology of the eye, it is natural to associate these ducts with the optic nerve. Although we might expect the term νεῦρα ('nerve' or 'cord') in this case, the technical medical vocabulary was not standardized at such an early date and these terms are not used consistently throughout the medical corpus. In the Hippocratic Corpus φλέβες are usually vessels that are hollow and carry liquid, so the description of them as ἄνικμος here is unusual; perhaps these ducts provide the empty space in the eye which Democritus says is necessary for vision.[21] However, it may also be that Democritus used φλέβες as a general term and described them as moistureless because they are more akin to the solid νεῦρα often associated with nerves, tendons and ligaments. It is difficult on these grounds alone to identify the φλέβες with the optic nerve,[22] but the ducts are also described as κατὰ τοὺς ὀφθαλμούς. Baldes, needing the ducts to travel through to the outer membrane of the eye, translates 'through the eyes', Taylor opts for the very general 'in the region of the eyes' and Burkert suggests that the ducts lead 'from the eye'.[23] For someone attempting to describe the eye in stages, starting from the anterior sclera and moving back to the optical nerve, the preposition κατά is as good as any for explaining how the nerve stretches back from the point where it attaches to the eye.

Textual problems at the end of our passage led Diels to emend καὶ μὴ εὐσχημονεῖν to ὡς ὁμοιοσχημονεῖν ('so that they have a similar shape').[24] This has the advantage of making Theophrastus' testimony match the evidence of Stobaeus, who categorizes Democritus among other philosophers who 'say that particular sensations occur when the pores are of the appropriate dimensions (συμμετρία), so

[20] LSJ s.vv. σομφός and χαῦνος. LSJ cite an occurrence of σομφός describing pumice (Alex. 124.10), but a *TLG* search produces only four instances of this combination, whereas a search with χαῦνος produces over 1900 results. Generally speaking σομφός is used less often than χαῦνος, being found mainly in the writings of the Peripatetics and medical writers, which may mark it as a technical term. Theophrastus' description of the medlar fruit as χαῦνος (*Hist. pl.* 3.12.5) may as easily refer to the hard, acidic fruit that falls from the tree as to its softer texture after months of sitting in the cellar. See also Craik (n. 7), 104.

[21] *Sens*. 54.6–7. Given Theophrastus' vigilance for self-contradiction, we should not be surprised to find these ἄνικμος vessels reported alongside the moist elements of the eye. In general the idea among medical writers seems to be that moisture facilitates motion, whereas dryness causes immobility. Cf. Hippoc. *Nat. puer.* 22.4 (VII.514L); *Morb.* 4.40.3 (VII.560L); *Carn.* 3 (VIII.586L); *Loc. hom.* 4 (VI.282–4L). See G.E.R. Lloyd, 'Diogenes of Apollonia: master of ducts', in M.M. Sassi (ed.), *La costruzione del discorso filosofico nell'età dei presocratici* (Pisa, 2006), 237–58; Craik (n. 7), 114–15.

[22] In Hippoc. *De arte* 10.16 (VI.18L) the νεῦρα, like everything else in the body, have cavities. Cf. Erotian, *Voc. Hipp.* col. N 7, who defines νεῦρον ἔναιμον as φλέψ.

[23] Baldes (n. 1 [1978]), 88–9; Taylor (n. 1), 109; Burkert (n. 1), 101.

[24] I follow Diels, *Doxographi Graeci* (Berlin, 1879), 513. Schneider emends to καὶ ὁμοιοσχημονοῖεν and Diels at DK 68A125 emends a second time to ὡς ὁμοσχημονεῖν.

that the appropriate sensible objects fit into each one' (DK 28A47). Bailey argues that the εἴδωλα are like the ducts in being hard and dry, and so 'like is known by like'.[25] Taylor remarks that the end of this passage suggests that it is Democritus *verbatim* rather than in paraphrase, and notes that if this is a clue that Democritus accepted the Empedoclean principle of like to like, it is isolated.[26] Precisely what it would mean for the ducts and the *imprints* to have a similar shape is unclear, but if we take our lead from Stobaeus, it may be that the imprints must be of a certain size for the ducts to 'recognize' (γνωρίζειν) and accommodate them.

We can now step back and evaluate Theophrastus' presentation of the Democritean account of the eye. If my general reconstruction is right, Theophrastus has done rather well. His account distinguishes surface and key interior elements of the eye necessary for vision, while also reporting what facilitates and what impedes vision. The only serious ground for complaint is the lack of explicitness about how these parts relate. Whether this is a weakness of Theophrastus or of the original source material is impossible to determine. However, if we can judge Theophrastus' priorities from the criticisms he makes, his main concern is the visual process itself; retaining any description of the eye in this section of the *De sensibus* is an additional benefit and a sign of his thoroughness.

What, then, is to be our assessment of Democritus' physiology of the eye? The general elements of the description are remarkably similar to our evidence from roughly contemporary technical sources, including the theories of Alcmaeon, Empedocles, Anaxagoras and the Hippocratic treatises. Nowhere does Democritus differ wildly from his predecessors and contemporaries, which is as we should expect, particularly if he is drawing on the expertise of others. The details preserved in this passage also suggest that he relies upon close observation or dissection for information about the interior portions of the eye, and possibly even for the account of the ducts leading from it. The most important element of the account is that the moist softness of the eye allows it to admit, retain and transmit the entering image. The ophthalmological description explains how the construction of the eye allows the effluence (εἴδωλον) and air imprint to pass through, rather than to 'beam back', as Aristotle suggests an ἀνάκλασις would. Theophrastus was certainly aware of Aristotle's criticisms, and elsewhere in the *De sensibus* he is eager to point out difficulties with the theories of his predecessors, but he remains silent on this point. The point of Democritus' physiology of the eye seems to be that vision occurs because the eye allows the image *in*, and its sponginess aids the transmission of the image to the reasoning faculty. Thus, Democritus' ophthalmology plays an important, though neglected, part in his theory of vision.

University of Oxford KELLI RUDOLPH
kelli.rudolph@philosophy.ox.ac.uk

[25] C. Bailey, *The Greek Atomists and Epicurus* (Oxford, 1928), 167.
[26] Taylor (n. 1), 109. Cf. von Fritz (n. 1), 91–4.