Democritus' Conventionality of Colour

Abstract: In this article, I establish, through a detailed analysis of Democritus' multi-dimensional account of colour, the physical basis for his claim that colours are 'by convention'. Uniquely among the Presocratics, he posits four basic colours, which arise from an interplay of light, air and the variable microstructures of objects. Such an account allows Democritus to explain both the mechanics of deceptive appearances and the formation of a φαντασία, which for the atomist is the representational content of perception, qualitatively different and ontologically distinct from the effluence.

Democritus is the earliest theorist to differentiate four, rather than two basic colours.[1] As we learn from a handful of scattered references in our later sources, Democritus provided this unique theory of colour, perhaps outlined in the now lost *On Colours*.[2] Our most important source of information about his explanation of sensation, including colour, is Theophrastus' critical, detailed account of pre-Aristotelian opinions in the *de Sensibus*, upon which my attention will largely focus.[3] Democritus refines the view, common among his predecessors,[4] that visible colours are intermediate between bright and dark, to suit his

[1] With some modification, Democritus' four colours (DK 68 A125 = Aët. 1.15.8) are analogous to the black, white, red, and yellow associated with the humoral theory of the body (cf. *DS* 43 = DK 64 A19 and A29a, on the predictive qualities of these four colours for health), and of the Greek *skiagraphia* palette (DK 31 B23. Cf. ps-Arist. *Mu.* 396b12; Cic. *Brut.* 70 and Plin. *Nat.* 35.29.44, 50). Aetius erroneously attributes the four-colour theory to Pythagoras and Empedocles: Sassi (1978) pp. 138-139; Ierodiakonou (2005) pp. 10-18.

[2] Listed among the Atomist's works on nature in the Thrasyllan catalogue, D.L. 9.46.

[3] I will cite Theophrastus' *de Sensibus* as *DS* throughout. All translations are my own unless otherwise stated.

[4] See Ierodiakonou (2004), (2005) on Empedocles, for whom all visible colours occur on a continuum between the extremes of bright (associated with fire) and dark (associated with water). Theophrastus attributes similar views to Anaxagoras (*DS* 27) and Diogenes (*DS* 42), for whom the difference between the darkness of the eye and the light of day is of explanatory importance. Similar interest in what we might consider a continuum of colour from dark (black) to light (white) is found in Plato (*Tim.* 67c4-68d7) and Aristotle, (*Sens.* 439b15-440b25, 442b21-29; cf. *Mete.* 374a4-375a29). Ps.-Aristotle (*Col.* 791a1-792a5) adds the yellow of flame as a

preference for making colour conventional.[5] He retains a certain correlation between darkness and air (*DS* 81), and brightness and light (*DS* 80). I examine the implications this has for his approach to colour vision, the φαντασία and visual errors below. Theophrastus asserts that bright and dark are opposites in Democritus' theory, but expresses uncertainty about whether his other basic colours, red and green, are also contrasting (*DS* 82).[6] By correlating fire's brilliance and luminosity with λευκόν ('bright') and its warmth with ἐρυθρόν ('red'), Democritus makes an important distinction between a colour's brilliance and its temperature. μέλαν ('dark') is associated with shadow in the surviving fragments, but about his fourth basic colour, χλωρόν ('green'), little information remains. Theophrastus gives a highly condensed account, namely that this colour is atoms and void 'configured in large portions' (*DS* 75). In addition to these explanations of the basic colours, from which all others are derived, Theophrastus also summarises Democritus' mixed colours. The descriptions of these colours, rich in technical vocabulary, provide us with insight not only into Democritus' understanding of the conventionality of colour, but also into his approach to perception more broadly. This, then, forms the bulk of our evidence for Democritus' theory of colour.

Despite advances in our understanding of ancient colour theory,[7] the treatment of

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third elemental colour. For further discussion see Ferrini (1999) and Struycken (2003); regarding the continuum see Hahm (1978) pp. 60-95.

[5] DK 68 B9 = Sextus Empiricus, *M.* 7.135. Cf. D.L. 9.72; Galen, *On Medical Experience* 15.7, *On the Elements according to Hippocrates* 1.2. For discussion see Pohlenz (1953); Heinimann (1965); Graeser (1970); Barnes (1982) pp. 370-377; McKim (1983), Sedley (1983), (1988), (1992b); Wardy (1988); Vander Waerdt (1989); Furley (1994); O'Keefe (1997); Ganson (1999); Curd (2001); Lee (2005); Mourelatos (2005); Pasnau (2007). Cf. Taylor (2007).

[6] Whether pairing red and green implies an understanding of complementary colours and successive colour-contrasts is unclear. Arist. *Insomn.* 459b11-13 seems to have no such understanding. The concept of colour constancy also seems to go unnoticed (*DS* 80).

[7] Ancient Greek authors' use of colour-terms has been subject to controversy since Goethe (*Zur Farbenlehre* (1810)), postulated that the Greeks were unable to see certain colours, on which see Schindler (1964) and Bradley (2009). Gladstone's (1858) support for Goethe's suggestion spurred philological research into Greek

Democritus' colours has changed very little over the years. Most scholars provide a list derived from Theophrastus' account, but do little to analyse the atomist's explanatory methods or the structures of the colours other than black and white.[8] Those who do so presume he is discussing the mixture of pigments, leading to the conclusion that he is colour-blind[9] or lacked experience, since as mixed paints, the suggested combinations fail to produce the right colour.[10] Few scholars have taken up Kranz's suggestion that Democritus' mixtures refer to colours in nature,[11] but Struycken's comparison between the Democritean account

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colour theory (e.g. Veckenstedt (1888) p.162), on which see Young (1964); Osborne (1968); Irwin (1974) pp. 6-7; Dürbeck (1977). Platnauer (1921) identified fine subtleties in Greek colour categories, despite ultimately supporting the colour-blindness theory. Cf. Rowe (1972) pp. 330-331 who assumes Homer's usage mirrored contemporary colour perception. Müller-Boré (1922) pp. 43-44 suggests that a lack of interest in colour is a sign of epic style. Maxwell-Stewart (1981) regards sense perception and colour theory as irrelevant factors in analysing 'normal' Greek colour terms, cf. Irwin (1974). New perspectives on colour theory abound in the 21st century: see Beta and Sassi (2003); Cleland et al. (2004); Sassi (2005); Rouveret, et al. (2006); Tanner (2016). Clarke's (2004) study of linguistic prototypes that act as points of reference for colour terms is particularly suggestive, and Villard's (2002) work on colour-terms in the Hippocratic Corpus provides further support for their close association with luminosity, texture, and contrast rather than hue.

[8] Beare (1906) pp. 33-37 lists the mixtures. Osborne (1968) p. 282 rejects early Greek philosophical explanations of colour as 'hotpotch', and Dürbeck (1977) concludes that we are unlikely to understand Democritean and Platonic colour terms. Bruno (1977) p. 74 states that Democritus' colours are not akin to those used by artists, but are 'in accordance with some imagined resemblance (obscurely described in considerable detail, now almost impossible to interpret)'. Taylor's (1999) notes on the *DS* provide cursory commentary. von Fritz (1953), Baldes (1978), Hahm (1978) and Maxwell-Stewart (1979) are exceptions, but provide analysis only of black and white.

[9] See Luria (2007 [1970]) pp. 1182-1183.

[10] See Hahm (1978) pp. 69-71. Guthrie (1965) p. 446 suggests that Democritus describes pigments, as do Taylor (1999) p. 117 n.115 and Baltussen (2000) pp. 118-120. Gage (1993) p. 12 asserts that Democritus had no experience mixing colours and Bailey (1928) p. 169 regards the Atomist's approach as abstract rather than empirical. Siegel (1959) is an outlier; he asserts that an experimental mixing of four standard pigments does produce the mixed colours in the Democritean report, but his actual discussion contradicts that claim.

[11] Kranz (1912) pp. 133-134. According to Stratton (1917) pp. 198-202, A.E. Taylor suggests that Democritus' account refers to a variety of exempla including pigments and natural phenomena. See also Sassi (1978) p. 147.

and the pseudo-Aristotelian *de Coloribus* is an admirable exception.[12] One of the weaknesses of existing scholarly interpretations is that they expect Theophrastus' account to be consistent in itself as a report on colour, when what we actually find is that Democritus' descriptions are as much about variously textured structures as the colours that arise from them. I argue that Democritus' multi-explanatory approach provides the key to understanding the conventionality of colour. His general claims about bright and green set the stage for a new interpretation of his detailed explanations of colour vision. I argue that Democritus' microstructural account, with its focus on predominance, is essential for an atomist understanding of colour perception via the air imprint. Finally, I propose that this account has vitally important and long overlooked implications for resolving the apparent contradiction between explanations that rely on observation and the scepticism that results from the errors that arise in perception.

The General Account of λευκόν and χλωρόν

Theophrastus' account of Democritus' colours begins with a correspondence between the smooth and the bright (λευκόν).[13] The singular τὸ λεῖον marks this out as a general claim, separate from the plural bright things in the lines that follow.[14] Smoothness is not an explicit feature of luminous, hard or rough things, and only appears in the description of friable objects to explain the absence of shadows. Elsewhere in the account of Democritus' theory of sensation, λεῖον is a feature of atomic shape,[15] but the adjective need not exclusively

[12] Struycken (2003) draws heavily on pseudo-Aristotle to reconcile Democritus' account with the most 'natural' explanations for colours.

[13] *DS* 73.2 = T1(a).

[14] In conversation on 18 May 2018, Katharina Ierodiakonou suggested that what Theophrastus outlines in these opening lines is Democritus' categorisations of various sub-species of bright, with that of smooth standing alongside hard and friable. While I see the appeal of such an explanation, the atomic structures described as hard, friable, and even rough exhibit a smooth arrangement, which accounts for their colour, thereby illustrating the general point.

[15] See *DS* 65-67, where λευκόν and τραχύς are among the atomic features responsible for tastes.

demarcate atomic features here. Some might argue that 'not rough' (μὴ τραχὺ) in the next sentence also refers to the atomic shape responsible for brightness, but the other terms in the parallel construction (μηδ' ἐπισκιάζῃ and μηδὲ δυσδίοδον) certainly cannot apply to atoms. This suggests that a smooth microstructural arrangement is the primary component of the atomist explanation of λευκόν. Smoothness manifests differently from one type of object to the next: luminous and hard things are smooth because they have straight pores, whereas friable and rough objects exhibit smoothness because their atoms are uniformly arranged.[16]

The case of green (χλωρόν) is more general still.**[17]** Theophrastus reports that 'green is composed of the solid and the void, both of them in large portions, and its colour is due to their position and order,'[18] and then criticises Democritus for being too vague.[19] However, the level of detail Theophrastus preserves for the other colours, both primary and combined, makes this generality suspicious. It may be that Theophrastus' source material did not present a full report: he may have been working from an imprecise epitome, a corrupt text, or a work that failed to account fully for this colour. Alternatively, something in the original context of Democritus' treatise may have suggested to Theophrastus that he could omit the explanation.[20]

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[16] See DS 66 for the link between 'unrounded', 'salty', 'rounded' and 'smooth'. T1(c) reveals that bright friable objects are shadowless 'because they are smooth and flat', which likely refers to the atomic structure rather than the atomic shapes themselves.

[17]DK 68 A124 (Aët. 1.15.8) substitutes ὠχρόν for χλωρόν, due to the association of Democritus' theory with the four-colour palette. The corruption is old, see *DG* 50 and *ad loc*.; also cf. Sassi (1978) pp. 138-139.

[18] *DS* 75.9-11: τὸ δὲ χλωρὸν ἐκ τοῦ στερεοῦ καὶ τοῦ κενοῦ συνεστάναι † μεγάλων ἐξ ἀμφοῖν, τῇ θέσει δὲ καὶ τάξει αὐτῶν τὴν χρόαν. Struycken (2003) correlates red with heat, white with light, black with air, and green with sprouting plants, sap, and water. Irwin (1974) pp. 31-78 similarly suggests that χλωρόν implies fluidity and liquidity in Greek poetry, drawing similar conclusions about the importance of χλωρόν for signifying young, growing plants. See also Prantl (1849).

[19] *DS* 82.

[20] Such an obvious oversight may be a sign of Theophrastus' overliteral close reading of a text. This seems to be the case with Theophrastus' treatment of Plato's mixed colours (*DS* 86) and critique at *DS* 91. See Rudolph (2018a).

Theophrastus' report does not specify whether the arrangements responsible for colour occur only on the object's surface or throughout its structure. Some scholars prefer to speak of the 'surface' of Democritus' objects,[21] but do not indicate how deep they assume it extends. Since Democritus asserts that atomic effluences stream off objects at a rapid pace, this surface must be many, many atoms thick. Moreover, such an explanation downplays the importance of an object's dimensionality and the language Democritus uses to express it. I prefer to speak in terms of Democritus' microstructural arrangements, fully acknowledging that he need not think objects have the same atomic arrangement all the way through. In the following analysis I explore how a variety of atomic arrangements result in a variety of textures, which nonetheless exhibit general characteristics, like those set out above, in order to produce a single visual effect.

The detailed examples that follow each employ idiosyncratic technical and analogical vocabulary, suggesting that they derive from Democritus' own text or an epitome. Democritus provides multiple explanations in order to demonstrate that atomic arrangement can produce a single colour despite a variety of surface textures.[22] This visual effect, I argue, is the result of a dynamic interplay of atoms, which provides a physical basis for the conventionality of colour.

Detailed Accounts of Colour

λευκόν

We turn now to Democritus' detailed accounts of the four basic colours, starting with the bright.

T1 Theophrastus, *de Sensibus* 73.2-4

(a) λευκὸν μὲν οὖν εἶναι τὸ λεῖον.

[21] For Kranz (1912) p. 131 shape and position are jointly responsible for colour; cf. von Fritz (1953) p. 97.

[22] The structure of Theophrastus' report is worth noting; he has delayed his report of the unusual rough brights and smooth darks to his critique in order to emphasise his point about the seemingly contradictory nature of Democritus' account. Such an approach is not necessarily negative, since it may have led him to preserve more of Democritus' account than he might otherwise have presented. See Rudolph (2018a).

(b) ὃ γὰρ ἂν μὴ τραχὺ μηδ’ ἐπισκιάζῃ μηδὲ δυσδίοδον ᾖ, τοιοῦτον πᾶν λαμπρὸν εἶναι. δεῖ δὲ καὶ εὐθύτρυπα καὶ διαυγῆ τὰ λαμπρὰ εἶναι.

(c) τὰ μὲν οὖν σκληρὰ τῶν λευκῶν ἐκ τοιούτων σχημάτων συγκεῖσθαι οἷον ἡ ἐντὸς πλὰξ τῶν κογχυλίων· οὕτω γὰρ ἂν ἄσκια καὶ εὐαγῆ καὶ εὐθύπορα εἶναι.

(d) τὰ [δὲ] ψαθυρὰ καὶ εὔθρυπτα ἐκ περιφερῶν μὲν λοξῶν δὲ τῇ θέσει πρὸς ἄλληλα κατὰ δύο συζεύξεις,[23] τὴν δ’ ὅλην τάξιν ἔχειν ὅτι μάλιστα ὁμοίαν. τοιούτων δ’ ὄντων ψαθυρὰ μὲν εἶναι, διότι κατὰ μικρὸν ἡ σύναψις· εὔθρυπτα δ’, ὅτι ὁμοίως κεῖνται· ἄσκια δέ, διότι λεῖα καὶ πλατέα·

(e) λευκότερα δ’ ἀλλήλων τῷ τὰ σχήματα τὰ εἰρημένα καὶ ἀκριβέστερα καὶ ἀμιγέστερα εἶναι καὶ τὴν τάξιν καὶ τὴν θέσιν ἔχειν μᾶλλον τὴν εἰρημένην.

(a) The smooth is bright.

(b) For whatever is not rough, shadowy or hard to pass through, everything such as this is luminous. And it is necessary for the luminous things to be straight-pored and translucent.

(c) Among bright things, the hard ones are arranged from such shapes, like the inner ‘plate’ of shells, for in this way they would be shadowless and shining and have straight pores.

(d) Those bright things that are friable and fragile are composed of rounded shapes and are oriented crosswise relative to each other in two parallel columns, in an arrangement that is as uniform as possible overall. Such being the case, they are friable because the points of contact are small, and fragile because they are uniformly arranged. They are shadowless because they are smooth and flat.

(e) The more exact and unmixed the above-mentioned shapes are, and the more of the above-mentioned order and placement they have, the brighter they are.

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[23] I read συζεύξεις with the manuscripts, but accept Schneider’s κατὰ δύο. PF read: καὶ τὰ δύο συζεύξεις. Stephanus corrected to καὶ τὰς δύο συζεύξεις. For the plural with δύο see Smyth §999.

λευκόν, often rendered ‘white’ in English, is regularly associated with brightness rather than hue, particularly in early Greek literature.[24] The causal γὰρ at the beginning of the second sentence connects the general correspondence between the bright and the smooth with luminosity (τὸ λαμπρὸν) or ‘glow’, which we will later see is a point of intersection between red and bright. The three adjectives that characterize the luminous—not rough (μὴ τραχὺ), not shadowy (μηδ’ ἐπισκιάζῃ), and not hard to pass through (μηδὲ δυσδίοδον)—feature in every example of brightness that follows, even in the description of rough brights, postponed until Theophrastus’ critique (T2 below). Theophrastus criticises (*DS* 80.3-4) Democritus for speaking generally of ‘the nature (τὴν φυσίν) of transparency (τοῦ διαφανοῦς) and luminosity (τοῦ λαμπροῦ) rather than of white (τοῦ λευκοῦ)’. I will return to this objection below, but for now, it is clear that the brightness of white is central to Democritus’ account. Thus, I will translate λευκόν as ‘bright’ in order to keep the emphasis on its connection with light at the forefront of our discussion.

Hard λευκός

The explanation of the hard brights (T1(b)) focuses on three characteristics: shadowless (ἄσκια), shining (εὐαγῆ) and straight-pored (εὐθύπορα), which are synonymous with the general description of luminous brightness in T1(a). Many scholars assume these descriptors are illustrated by a reference to the inner *surface* of shells, and that further explanation has

[24] Homer uses λευκόν when describing things we would typically call white (animals, wings, clothes), but also things we would not, e.g. the sun (*Il.* 14.184-185), wind (*Il.* 21.334-335) and the colour of the sky (*Od.* 6.4-45). Even in ps.-Arist. *Col.* 794a13-15 there is evidence that bright and white are seen in combination. Theophrastus’ criticism suggest that he was aware of a distinction between colour saturation, brightness and hue, although the separation of λαμπρόν from λευκόν goes back at least to Plato (*Ti.* 67c4–68d7). For the correspondence between white and brightness in Greek poetry, see von Fritz (1953) p. 96; Irwin (1974); Baldes (1978) p. 90; Hahm (1978) pp. 69-70.

been elided,[25] but a closer analysis reveals the explanatory role the reference to shells has for Democritus' theory.

Before assuming that Theophrastus summarised this example as a mere illustration, we should evaluate the phrase ἡ ἐντὸς πλὰξ τῶν κογχυλίων ("the inner 'plate' of shells") as part of the Democritean explanation. As such, it provides some clarity about the structural elements that compose hard, bright objects. Maxwell-Stewart suggests a particular concrete explanation, arguing that Democritus' analogy is based on oyster-shells which have lost their periostrakon and been perforated by the sponge *Cliona*.[26] Although this accounts for the necessary terms of the description, the simplicity of it does not warrant such a specific explanation. Moreover, κογχύλιον, used here, is a general term for shell and only rarely used of the oyster (usually called ὄστρεον). This is therefore a tendentious reading of the text, and an unlikely solution to the problem.

Since the term κογχύλιον 'connotes the form rather than the substance of the shell',[27] this suggests that something about its shape and not just its surface is relevant to the account. Moreover, πλάξ literally means 'flat' and is used to describe gold plates, leaves, and marble slabs. Understood as 'plate', it may signify the inner portion found in the shells of the common calyptraeidae family of molluscs, which is usually a plate- or cup-like structure to which the animal's muscle attaches. This 'plate' is bright white (whatever the exterior shell colour), translucent and hard.[28] These inner 'plates' may have suggested the subsequent three-fold description of shells as shadowless (though shiny), because the light passes through them; hard because they are made of the same material as the rest of the shell's inner coating; and having straight pores, since they are also striated, which may have suggested a

[25] Indeed, LSJ cite this occurrence of πλάξ as meaning 'surface'. See Taylor (1999) p. 115. Stratton (1917) p. 133 and von Fritz (1953) p. 96 translate "cockle shell", which is particularly misleading, since cockle shells do not have uniformly white interiors. Beare (1906) p. 31 translates: "of white objects, those which are hard – as, for example, the flat inner surfaces of bivalve shells – consist of such atomic shapes" also misses the point.

[26] Maxwell-Stewart (1979).

[27] Thompson (1947) s.v. κόγχη.

[28] Wye (1991) s.v. Calyptraeidae.

straight-pore atomic structure. On this interpretation, the shell is a paradigmatic example of hard bright substances, as Democritus defined them.

The shell reference may also clarify the immediately preceding allusion to composition from shapes. Baldes, following von Fritz, takes σχῆμα to refer to the atomic structure rather than the shapes of individual atoms themselves, but neither scholar adequately explains what such a structure may be.[29] Indeed, von Fritz goes so far as to attribute 'atoms with hooks' to hard objects, but provides no reference or reasoning for this assumption.[30] One possibility is that Theophrastus chose to retain the example of the natural phenomenon, but in an attempt at brevity, omitted the details of the shapes. Alternatively, τοιούτων may refer back to the general descriptor 'smooth' in the opening sentence. However, since Theophrastus' criticism at *DS* 79 explicitly relies on a difference between the shapes of hard and friable brights, it would be odd for him to have omitted the shape term altogether in his report.[31] Theophrastus clearly specifies that the shapes of friable objects are "rounded" and the only term in T1(c) that could apply to an atom yet be substantially different from those of the friable brights is πλάξ. Thus the shell-like plates not only are an example of a hard, bright object and a striated structure, but also are metonymic for the atomic shapes that predominate in such objects. Democritus need not have limited the use of the shell analogy to one level of explanation. Rather, it may be that he mentioned the shell – and Theophrastus preserves it – because it provides a dual explanation at the atomic and structural levels.

One potential objection is that the description of hard brights tells us more about an object's hardness than its brightness. In fact, since the description of hard brights is terse, it

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[29] Baldes (1978). Cf. Beare (1906) p. 31 and Taylor (1999) p. 115.

[30] von Fritz (1953) p. 97.

[31] See Rudolph (2018a) and Baltussen (2000) on Theophrastus as a source. In general, Theophrastus is a careful reporter of his predecessors' theories, preferring to criticize the information in his report, while occasionally delaying evidence from his predecessor that he thinks will strengthen his critique. It is odd for him to omit key evidence in support of his point. However, summarizing complex explanations clearly and concisely runs the risk of oversimplification, even for modern scholars.

may seem that the subsequent description of friable brights is intended as a deviation from this standard. The description of hard correlates this tactile property with density and a lack of void (*DS* 62). However, Seneca preserves a more detailed summary of Democritus' understanding of the atomic arrangement of hard objects that rules out this objection. At the end of his discussion of why snow forms in the warmer atmosphere near the earth, Seneca moves beyond the atomist's correspondence between hardness (*solidius*) and density (*pressiora*), to focus on the microstructure rather than on atomic shapes or the object's surface. According to Seneca, Democritus 'says that in those bodies that are harder and more compressed, the pores are necessarily smaller and the flow of *spiritus* is thinner in each one.'[32] He emphasises the relation between density, hardness, and the porous microstructure, which is invisible to the eye. An object could easily exhibit pores that were narrow and

[32] *Quaestiones Naturales* IVB.9–10 = Taylor (1999) *testimonia* 162, p. 135; not in DK or Luria (1970): *accedit his ratio Democriti: omne corpus, quo solidius est, hoc calorem citius concipit, diutius servat. itaque si in sole posueris aeneum vas et vitreum, aeneo citius calor accedet, diutius haerebit. adicit deinde quare hoc existimet fieri. his, inquit, corporibus quae duriora et pressiora sunt necesse est minora foramina esse et tenuiorem in singulis spiritum; sequitur ut, quemadmodum minora balnearia et minora miliaria citius calefiunt, sic haec foramina occulta et oculos effugientia et celerius fervorem sentiant et propter easdem angustias, quicquid receperunt, tardius reddant.* 'The account of Democritus resembles this type. The more dense every body is, the more quickly it receives heat and the longer it keeps it. And so if you put a bronze vase and a glass one in the sun, the heat will enter the bronze more quickly and stay longer. Next he adds why he supposes this happens. He says in those bodies which are harder and more compressed, the pores are necessarily smaller and the flow of air is thinner in each one. It follows that, just as smaller bathtubs and smaller containers for heating bath water heat up more quickly, so these pores (that are concealed and escape the sight) are affected by (lit. feel) the heat faster, and because of that same narrowness, they give back whatever they have taken in more slowly.' On baths, a tall and narrow vessel for drawing and warming water, Pall. 1, 40; Sen. *QN* 3.24.2, 5.13.4; Paul. *Sent.* 3.6.65. Sen. *QN* 5.13.4 suggests three forms of air: strong-moving (*vehementior*) *ventus*, slower flowing (*fluens*) *spiritus* and the generic *aër*; cf. Plin. *NH* 2.5.4, who suggests *spiritus* is a synonym for Latin *aër* and Greek ἀήρ. Given the context specifies the reception of heat, it is perhaps better to assume *spiritus* reflects the Democritean association of atoms that constitute heat and soul (see note 58 below). See Sen., *Ep.* 104.2 for the use of *spiritus* as something more akin to 'life breath'. See Rudolph (2009) on the importance of motion for heat in Democritus' physics.

straight (especially if its atoms were flat and compressed into tight stacks), which would explain why it is, like the shell, both hard and bright. Thus, in addition to providing a multi-dimensional explanation of hard brights, T1(c) also reveal Democritus' explanatory method in which common objects can help elucidate the atomic properties responsible for colour and texture.

Friable and Fragile λευκός

The brightness of fragile and friable textures (T1(d)) is the result of an atomic structure constrained, in part, by the possible configurations of the atomic shapes that constitute them. Theophrastus separately specifies the microstructures responsible for friability and fragility, leaving implicit those features responsible for colour. What is striking is how different this account is from that of hard brights, which suggests that colour is conventional precisely because it arises from multiple configurations, which nonetheless share a subset of structural relations.

Democritus specifies that the shapes of friable and fragile brights are περιφερές, often assumed to mean spherical.[33] These atomic shapes are λοξῶν δὲ τῇ θέσει πρὸς ἄλληλα κατὰ δύο συζεύξεις; Taylor provides a typical translation: 'positioned obliquely in pairs'.[34] If we assume the atoms are spherical, Democritus must mean that the pattern of arrangement is

[33] Taylor (1999) p. 116 translates 'spherical', as does Beare (1907) p. 31. A. E. Taylor *apud* Stratton (1917) p. 197 entertains both possibilities, but only provides a diagram of the spherical option. περιφερές must refer to the shape rather than the structure of the atoms. Baldes (1978) p. 91 refers to "rounded structures", but concedes that the description which follows refer to the orientation of atoms themselves. Nothing in the grammar or syntax of the passage requires such a distinction; it is simpler to render the Greek as I have done, so that the description of the orientation and the adjective "rounded" both refer to the atoms themselves. It is also possible to read the adjectives 'smooth and flat' at the end of T1(c) as a further clarification of the atomic shapes responsible for shadowlessness (ἄσκια), but as I argue below, this too seems part of the structural description.

[34] Taylor (1999) p. 116. See also Stratton (1917) p. 133: 'placed oblique to one another and oblique in their conjunction by pairs'; Graham (2010) p. 589: 'oriented at an angle to each other and joined in pairs'.

quincuncial (see Figure 1),[35] but as Stratton remarked 100 years ago, defining pairs of atoms in this pattern is difficult. If, however, we understand the phrase as 'oriented crosswise relative to each other in two parallel columns',[36] then Democritus must mean pairs such as AB and BC in a quincuncial array. In this way, the orientation (θέσις/τροπή) of the shapes remains aslant and the arrangement (τάξις/διαθιγή) is uniform, but even so, identifying these atoms as 'pairs' is not a straightforward matter.

[Insert Figure 1 Here]

The arrangement can be explained better if we interpret περιφερές as 'oval' since, at most, the term means 'rounded'. Unlike spheres, ovals can easily be placed crosswise to one another in parallel rows (Figure 2 & 3) or distinguishably at acute angles (Figure 4). Additionally, we are told that the points of contact between the atoms are small. The advantage of a construction like Figure 3 is that the atoms are all in contact with one another. Although not an explicit stipulation in T1, it does make for a more robust interpretation of the text. Furthermore, structures configured like those in Figures 2, 3 and 4 would create straight-pores running in uniform parallel columns, which would produce a shadowless effect. The fact that such pores may also provide some tactile qualities does not diminish their role in colour formation. Indeed, such an account makes clear how a single structural feature can present two simultaneous sensory experiences – brightness and friability – for different organs of perception.

[Insert Figure 2, Figure 3 and Figure 4 in a single row here]

[35] Beare (1906) p. 31; Stratton (1917) p. 178.

[36] LSJ s.v. συζεύγνυμι, 2.b.; see Ascl. Tact. 11.2 where κατὰ συζεύξις is used of armies marching in 'two parallel columns'.

An objection may be raised to this reconstruction from proponents of the non-contact interpretation of atomic physics, according to whom atoms never actually touch, since, on their account, two touching atoms would have to become one.[37] For them, σύναψις must mean 'cluster' rather than 'point of contact', referring to the pairs of atoms – spherical or oval – that are oriented crosswise or at acute angles. It is not clear, on their interpretation, what κατὰ μικρὸν would mean, since it is difficult to define a small cluster 'in an arrangement that is as uniform as possible throughout'. Even if these scholars make σύναψις equivalent to Democritus' διαθιγή (which literally means 'mutual contact'), it is still unclear what it means for the arrangements of the atoms to be 'small throughout'. I prefer to understand σύναψις literally: Democritus' atoms touch.[38] μικρὸν indicates that the area of contact between two adjacent atoms is small. In fact, as we know from Euclidean geometry, circles placed next to each other only touch at one point (although another Abderite, Protagoras, denied it); Democritus may be describing this point.[39] Thus, the structure described here would crumble easily since connections between atoms are easy to separate, and unlike the compressed, narrow pores of hard, bright objects, these arrangements create loose lattice structures, with seams along which the object could break.[40]

Friable brights explicitly share the characteristic of shadowlessness with all the other bright examples preserved in the *DS*. In this particular case alone, however, it is ascribed to the smooth (λεῖα) and flat (πλατέα). It is not plausible to assume these terms refer to the atomic shapes, primarily because the shape responsible for these features has already been specified as rounded. Moreover, we would not expect Theophrastus to err in his criticism that the shapes responsible for hard brights differ from the friable (*DS* 79). Finally, it would be odd for Theophrastus to sandwich a redundant description of shape between his summary of the microstructural account and his generalising programmatic statement concerning

[37] See Taylor (1999) pp. 186-188; cf. Kline and Matheson (1987); Godfrey (1990).

[38] See also Bodnár (1998) p. 46ff.

[39] Euclid, *Elements* 3.13. On Protagoras see Arist., *Metaph.* B.2 998a1-19. Pl., *Ep.* vii 343A4-9. For discussion, see Pritchard (1995).

[40] Uniformity causes fragility, which resembles softness (*DS* 62).

predominance (T1e). It is therefore more likely that the shadowlessness associated with friable and fragile brights arises from smooth and flat microstructures, or that this is an interpolation of a marginal note.

Rough λευκόν

Finally, I turn to the postponed description of rough brights, presented in Theophrastus' critique.[41] This passage, with its verbal idiosyncrasies and unique description, preserves a direct quotation or close paraphrase of Democritus. The standard interpretation of the analogy is that these objects are formed of large figures whose connections are not round but 'serrated', 'stepped' or 'battlemented' (προκρόσσας). The shapes are broken (ἀγνυμέναις) like an ascent or a mound thrown up (χώματα) on the approach to the city wall (ἀνάβασις).[42] Although such interpretations seem to fit the language of the passage, it is not clear how they help us understand the shape and arrangement of this coloured texture, and scholars have not attempted a more refined analysis. A closer look at the terminology suggests that Democritus had a different, more specific example in mind: the approach to the city not by land, but by sea.

T2 Theophrastus, *de Sensibus* 79.7-13

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[41] This is a common technique. Theophrastus tends to postpone deviations from a general claim to use as evidence of a contradiction in the works of his predecessors. See Rudolph (2018a) and Baltussen (2000). Fortunately, this dialectical device does not detract substantially from the value of the text as a doxography. Indeed, Theophrastus' desire to highlight his predecessors' contradictions may have led him to preserve more of the details of their work.

[42] So Beare (1906) p. 35: 'these [rough brights] are formed of large figures of which the commissures are not indeed round but serrated, while the outlines of the figures are broken like stair-steps, or the tops of vallated mounds erected before the city wall'; see also Kranz (1912) p. 131. Stratton (1917) p. 139: 'the white things that are rough; these are of large particles, he holds, and their junctions are not rounded off but are 'battlemented', and the shapes of the figures are broken like the earthworks in the approach to a city's walls'. Taylor (1999) p. 117: 'They are composed of large atoms whose combinations are not round, but stepped, and the shapes of the atoms are combined like an ascent or a mound thrown up in front of a wall'.

καὶ πάλιν ὅσα λευκὰ τῶν τραχέων· ἐκ μεγάλων γὰρ εἶναι ταῦτα καὶ τὰς συνδέσεις οὐ περιφερεῖς, ἀλλὰ προκρόσσας[43] καὶ τῶν σχημάτων τὰς μορφὰς ἀγνυμένας, ὥσπερ ἡ ἀνάβασις καὶ τὰ πρὸ τῶν τειχῶν ἔχει χώματα· τοιοῦτον γὰρ ὂν ἄσκιον εἶναι καὶ οὐ κωλύεσθαι τὸ λαμπρόν.

And again, those rough things that appear bright: these, he says, are from large shapes, and their connections are not rounded, serrated, and the shapes of the atoms are broken like the jetties on the approach to the city's walls. For being of this kind, it is shadowless and the luminosity is not hindered.

Herodotus mentions Abdera as a major commercial centre in southern Thrace, noting its position on a promontory with a coastline suitable for the formation of a series of harbours.[44] One of these, constructed in Democritus' lifetime, may have been the inspiration for this account of rough brights.[45] Like its predecessor, it included a mole of granite blocks and rough boulders topped by light-coloured ashlar, connecting it to the city wall, and extending 170–180m westward from the eastern city wall into the harbour before turning north, thereby sheltering the harbour from the east and the south.[46] This may be the kind of shape Democritus intends in this description of rough brights.

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[43] προκόσσας PF: προκρόσσας Stephanus.

[44] Hdt. 6.46-47.

[45] See Samiou (1993) for details of the Abderite ports; on Abderite settlement see Graham (1992) and Tiverios (2008) pp. 91-8. Three port basins have been traced: two were made by extending the city wall, the third by an artificial breakwater. According to Κουκούλη-Χρυσανθάκη (1991 [1994]) p. 196, an archaic mole, with a rubble foundation probably topped by light-coloured ashlar blocks (on which see Κουκούλη-Χρυσανθάκη (1990) p. 101), was built at sea-level at the end of the sixth or beginning of the fifth century BCE, as an extension of the city wall (running east to west, sheltering the port from the north, and facing full south). When the archaic port silted in, a second was developed in Democritus' lifetime (the late fifth or early fourth century BCE); see Κουκούλη-Χρυσανθάκη (1991 [1994]) p. 195. The breakwater forming the third harbour basin is located in the Agis Giorgios area near Abdera.

[46] Samiou (1993) p. 365.

Atomic shape, described as ἀγνυμένας,[47] is an essential component of the description of rough brights. Hesychius reports that ἀγνυμένα is synonymous with πηδάλια (literally: rudder), used by Aristotle to describe grasshoppers' long hind legs.[48] Democritus then draws an analogy between the bent shape and the ἀνάβασις. χώμα need not be translated literally as 'mound' or 'earthwork', since it is commonly used to refer to moles or jetties on a waterfront.[49] The haphazard image of a mound is out of place among descriptions of bright objects, which we have seen exhibit orderly features and detailed arrangements. By contrast, interpreting χώματα as 'jetties', easily demarcates a specific shape, either that of the backwards L-shaped mole emerging from the city wall at Abdera, or a quay, with landing points jutting out on one or both sides.[50]

The nautical terminology continues with a description of the bindings or connections (συνδέσεις) these shapes create. They are unrounded and serrated (προκρόσσαι), a term used in Homer and Herodotus to describe the way ships jut into the sea when pulled up on the beach.[51] Tessellated L-shaped atoms could form smooth surfaces or straight passageways that exhibited, for example, herringbone-type patterns, and singly or doubly crenellated shapes could fit together like puzzle pieces or gears. In this way, smoothness is a feature of the structure, even if the shapes themselves are irregular. Such an arrangement could result in flat structures that would remain shadowless, and as Theophrastus reports, it is also luminous, meaning the structure allows light through, presumably through unobstructed pores.[52] Thus, it

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[47] LSJ s.v. ἄγνυμι. This term is used mainly by Homer and Ionian authors such as Herodotus and the Hippocratics, and covers a range of meanings including 'broken', 'fractured', 'splintered', 'winding' and 'bent'.

[48] Arist. *HA* 532a29, 535b12.

[49] LSJ s.v. χώμα. See also Hdt. 8.97.

[50] The best example of this is the quay at Teos, which founded the colony of Abdera. See Blackman (1973, 1982a, 1982b).

[51] LSJ s.v. προκρόσσοι; Hom. *Il.*14.35; Hdt. 7.118; cf. Hdt. 4.152.

[52] On letting light through see DK 68 A 89A. A third interpretation of T2 is also possible. Democritus could be referring to the rubble construction of the mole in which 'broken' large stones (ἀγνυμέναι) are arranged in rows (προκρόσσαι) to form the mole. In this case, the large, rough shapes would tessellate to form a smooth surface,

is possible for an object to exhibit both smooth microstructural properties responsible for brightness and rough features that account for its texture. It is worth noting that the dimensionality of the description is important here. Rough and irregular atoms might tessellate to form smooth, straight pores composing the microstructure of the object, but the surface edge of those irregular atoms would still potentially create a rough surface texture. This further suggests that an object's structure, not its surface, is important for colour.

The criticisms Theophrastus raises concerning Democritus' reliance on shape in the description of bright miss the mark.[53] He first chastises his predecessor for failing to assign colour to a single shape. However, variation is precisely Democritus' point: no single atomic shape or microstructure is responsible for the perception of brightness. Rather, common features like shadowlessness[54] or straight pores are the result of variations in composition that nonetheless produce a general quality: smoothness. Sometimes these variations can be explained by reference to atomic shape, sometimes by reference to structural features, but often both. Second, Theophrastus seems to understand the importance of the interplay of light, since he criticises Democritus for ignoring the way a three-dimensional shape inevitably casts a shadow in the presence of directional illumination. However, Democritus' point is not that the shapes are themselves shadowless. Indeed, a single atom casts no shadow because it cannot be illuminated by light, which is itself an atomic aggregate. Rather, in

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which would once again allow for luminosity. In this case, however, it is not clear what it would mean for the connections to be serrated, making this interpretation inferior to those presented above.

[53] *DS* 79.3-7: 'Secondly, there is the difficulty that he does not make one shape for all brights, but attributes a different shape to hard brights and friable brights. For it is not plausible that there is a different cause <of brightness> for things with different tactile properties. Nor yet could the shape be the cause of the difference, but rather the position, for spherical shapes too and, simply put, any shape whatsoever, can shadow themselves.' In *Od.* 64, Theophrastus also criticizes Democritus' theory of colour for explaining colours by reference to shapes rather than to the sense organ.

[54] It is worth noting that all of the examples of Democritean brightness feature shadowlessness as a key component of the microstructure. See below for further discussion of shadows and shadowlessness in Democritus' account.

Democritus' account of the bright he describes arrangements that would cast no *internal* shadow because they are straight-pored or smoothly tessellated. Thus, colour, for Democritus, cannot be reduced to a single shape, or even to a single arrangement of atoms.

Predominance, clearly outlined at T1(e), turns out to be the general principle guiding Democritus' explanation of colour.[55] First, because atomic shape places a limit on the types of connections that can arise in an arrangement, the predominance of particular shapes is significant for explaining perceptible qualities. Just as predominant cubic or cylindrical shapes among building blocks lend themselves to particular kinds of structure, so too the shape that predominates in a structure will limit the types of arrangements that can be formed, as well as the level of regularity and uniformity they can exhibit. Some shapes are suited to flat, dense stacks along straight lines, others to constructions in which atoms touch only at one point, and still others form interlocking or crenellated structures. Nevertheless, all these shapes, when combined in particular ways, create arrangements whose features consist of those necessary for brightness, namely smoothness, straight-pores, and shadowlessness.

Second, while predominance is a general principle of Democritus' atomism, in the case of colour it extends also to the microstructural properties. The more shadowless or straight-pored an arrangement is, the brighter it appears. An object that displays these characteristics would be noted for its exceptional brightness, and may garner agreement about its appearance from the majority of observers. An explanation by predominance, however, would also allow for those cases where the colour of an object is disputed, because the alignment of atoms in the object is either highly varied or able to change rapidly, or because the shapes responsible for the structure are so evenly balanced that it is difficult to pick one feature over another. Thus, the association of the bright with the smooth refers to a prevalent general feature associated with microstructural arrangements, instead of (or as well as) the shapes of the atoms.

To sum up, then, by focusing on broader features of atomic arrangement – smoothness, shadowlessness, and straight, unobstructed pores – Democritus' theory uniquely

[55] This is also true of Democritus' theory of flavours at *DS* 67.6-12, on which see Rudolph (2018b).

accommodates variation among objects sharing a single perceptual quality, namely brightness. The factor common to these multiple explanations is that they can allow light to pass into or through an object.[56] We may conjecture, then, that for Democritus, what makes an object bright is its ability to allow light to enter its structure. Objects that exhibit smoothness due to straight and shadowless pores allow light into them, so that when the effluence flows off the object, light accompanies it. In the case of smooth and flat objects, it may be that light is reflected with the effluence.

Red (ἐρυθρόν)

Like the preceding account of brights, Theophrastus' report of ἐρυθρόν preserves the role of atomic shape and arrangement in the formation of colour.

T3 Theophrastus, *de Sensibus* 75.1-9

ἐρυθρὸν δ' ἐξ οἵωνπερ καὶ τὸ θερμόν, πλὴν ἐκ μειζόνων. ἐὰν γὰρ αἱ συγκρίσεις ὦσι μείζους ὁμοίων ὄντων τῶν σχημάτων μᾶλλον ἐρυθρὸν εἶναι. σημεῖον δ' ὅτι ἐκ τοιούτων τὸ ἐρυθρόν· ἡμᾶς τε γὰρ θερμαινομένους ἐρυθραίνεσθαι καὶ τὰ ἄλλα τὰ πυρούμενα μέχρις ἂν οὗ ἔχῃ τὸ τοῦ πυροειδοῦς. ἐρυθρότερα δὲ τὰ ἐκ μεγάλων ὄντα σχημάτων οἷον τὴν φλόγα καὶ τὸν ἄνθρακα τῶν χλωρῶν ξύλων ἢ τῶν αὔων, καὶ τὸν σίδηρον δὲ καὶ τὰ ἄλλα τὰ πυρούμενα· λαμπρότατα μὲν γὰρ εἶναι τὰ πλεῖστον ἔχοντα καὶ λεπτότατον πῦρ, ἐρυθρότερα δὲ τὰ παχύτερον καὶ ἔλαττον. διὸ καὶ ἧττον εἶναι θερμὰ τὰ ἐρυθρότερα· θερμὸν [μὲν] γὰρ τὸ λεπτόν.

The red consists of the sort of things that also compose heat, except they are larger. For if the aggregations are larger, although the shapes are the same, they are more red. Evidence that red is from these sorts is found in the fact that as we get hot we redden, as do other things placed in the fire until they have a fiery colour. Things are more red when they are made from large shapes, for example the flame and coal of

[56] Theophrastus objects that Democritus' theory accounts for transparency and luminosity rather than colour (*DS* 80.1-7), but this seems to be precisely the point.

> green wood are more red than those of dry. Likewise iron too, and also other things placed in fire. For those are most luminous that have the largest quantity of fire and the finest, but redder are those that have thicker and less fire. That is also why redder things are less hot, for the fine is hot.

Democritus asserts a general correspondence between the colour red, heat, and largeness. Because there is an association between heat and spherical shapes in his account of sweet flavours, scholars have been quick to assume that Democritus makes red arise from spherical and large atoms.[57] However, in the next sentence, Democritus specifies that this association with largeness extends also to the microstructural aggregations of atomic particles, which marks out the first sentence as a general claim regarding the colour red.

Indeed, the majority of T3 adds qualifications to this account. Elsewhere fire and heat-generating particles are described as small, fast-moving, and spherical.[58] Moreover, it is clear from T3 that the size of the shapes and aggregates responsible for the colour red are defined in relation to those of fire. Thus, the shapes and aggregates that compose red are like heat, but larger (ln. 2) and thicker (ln. 8).

As in the case of bright, here too, multiple explanations are at work in the description of red. Democritus explains how larger shapes are responsible for red by referring to the example of burning green wood, which produces a smaller, redder, and cooler fire than dry wood due to the evaporation of water (ln. 5-6). Iron placed in the fire is a second example of the way largeness produces red. However, we know from the report of hard and soft at *DS* 62, that iron is irregularly composed (ἀνωμάλως συγκεῖσθαι), having void in many places and in large portions while still being condensed (πεπυκνῶσθαι). This suggests that iron is an example of how large aggregations and density can also produce a red colour.[59] As in the

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[57] See, e.g. Beare (1906) p. 32.

[58] Cf. *DS* 65.5-9, 68.8-9, 75.1-9. See also, Arist. *de An*. 403b25-404a16 (DK 67 A28), 405a8-13 (DK 68 A101); *PA* 652b8-15 (not in DK); *Resp*. 471b30-472a18 (DK 68 A106). See Rudolph (2011), Baldes (1975, 1978) and von Fritz (1953) on the role of the sun.

[59] Resulting from iron oxidization in the heating process.

case of hard and rough brights, natural and technological examples are a unique feature of Democritus' method of explanation.[60]

Democritus also marks out the upper limit of reddening in relation to brightness. Objects placed in fire redden 'until they have a fiery colour'. μέχρις is generally used to describe 'leading up to' or 'going as far as'.[61] The genitive that it modifies usually acts as a boundary, which suggests that the category of colours that are ἐρυθρόν goes as far as, but does not include, the fiery colour.[62] Fiery colours appear twice more in Democritus' account of the mixed colours, once as a component of the colour blue[63] and again on its own. The flame-like colour (φλογοειδὲς) is given multiple explanations, where it seems to be describing a very bright yellow.[64] As a variation of brown (καρύινον), it arises when the

[60] Examples related to fire abound in Democritus' account of colour, suggesting that some of these details may be drawn from his treatise 'Causes of Fire and the Things in Fire' (αίτίαι περὶ πθρὸς καὶ τῶν ἐν πυρί, D.L. 9.47).

[61] LSJ s.v. μέχρι.

[62] Struycken (2003) pp. 294-296 understands both φλογοειδές and πυρῶδες as sub-categories of red, but from the descriptions Theophrastus preserves, it seems more likely that like luminosity, this colour acts as the interface between red and bright. One might also assume that the description of the flame-like colour suggests that red occupies an intermediate position between bright and dark, but nothing about the surviving Democritean evidence suggests that his analysis of colour is linear.

[63] πυρῶδες combines with indigo to produce blue (κυανοῦν) at *DS* 77.8-10.

[64] *DS* 78.1-5: τὸ δὲ καρύινον ἐκ χλωροῦ καὶ κυανοειδοῦς. ἐὰν δὲ χλωρὸν μιχθῇ, φλογοειδὲς γίνεσθαι, τῷ γὰρ ἀσκίῳ καὶ μελανόχρων ἐξείργεσθαι. σχεδὸν δὲ καὶ τὸ ἐρυθρὸν τῷ λευκῷ μιχθὲν χλωρὸν ποιεῖν εὐαγὲς καὶ οὐ μέλαν· διὸ καὶ τὰ φυόμενα χλωρὰ τὸ πρῶτον εἶναι πρὸ τοῦ θερμανθῆναι καὶ † διαχεῖσθαι. 'Nut-brown is from green and blue-ish, but if green is mixed, it becomes flame-like, for the dark-black colour is expelled by the shadowless. And red, too, when mixed with bright produces almost a bright green and not dark-black; which is why plants are green at first, before they are heated and † diffused.' See Sassi (1978) p. 145. Struycken (2003) pp. 287-288 interprets σχεδὸν […] διαχεῖσθαι as a continuation of the description of nut-brown, and likens the mixture of bright and red to the maturation of plants described in ps.-Arist. *Col.* 795a1-15. See Bruno (1977) pp. 24ff. on the 4th century BCE tomb in Kazanlak, Bulgaria, where a dark brown colour is obtained by overlaying a blue wash on a yellow background.

addition of χλωρὸν causes the bright to expel the dark.[65] However, this colour can also be formed when red and bright mix; the changing colour of plants is given as evidence of this phenomenon.[66] In T3, the distinction is drawn with respect to luminosity (λαμπρόν). As we have seen in the case of brightness, luminosity is associated with straight-pored and translucent structures, and the absence of rough, shadowy or obstructed pores. Here, however, the focus is on the predominance of the finest (λεπτότατον) microstructural properties associated with fire. Redness can approximate this luminosity, but its ruddiness is a product of the denser structural properties it exhibits. Thus, brightness includes, but is not fully explained by luminosity, which features as a point of intersection between redness and brightness.[67] Here too we see that the predominance of particular structural features plays an important role in the formation of colour.

In addition to demonstrating how different microstructural properties can produce similar perceptual effects, Democritus' account of red also illustrates the similarity between what is seen and what is felt. Alongside the two examples of reddening objects, Theophrastus also preserves the evidence of a perceiver reddening as she becomes hot. Importantly, this suggests that the mechanisms that produce the colour red in external objects are also at work in perceivers.[68] The understanding that a perceiver has about her own experience of blushing or reddening when warm, provides insight into reddening in general. Thus, in addition to explaining the appearance of red, T3 also establishes the role of perception as a basis for empirical knowledge. This suggests that when Democritus claims that 'in fact we know nothing firm, but what changes according to the condition of the body and of the things that

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[65] I accept the emendation τῷ γὰρ ἀσκίῳ for τὸ γὰρ ἄσκιον in Diels *DG* ad loc. There is no reason to follow Diels-Kranz in adding καὶ λευκόν to the text.

[66] It is important to note that the mixture only produces a *nearly* bright/pure green; σχεδόν is emphasised by its prominence at the beginning of the sentence, suggesting that yellow from combination only approximates the colour of χλωρὸν.

[67] This makes Theophrastus' criticism (*DS* 80.3-4) that Democritus collapses white and bright inapposite.

[68] See Rudolph (forthcoming) on Democritus' tactile qualities.

enter it and come up against it',[69] he is setting out a basis for empirical research. Theophrastus bears witness to this interpretation, when at *DS* 64, we are told that Democritus uses 'humans as his reference point for the appearance (φαντασία)'. At the very least, this evidence should make us question the portrayal of Democritus as a proto-sceptic about whether one may come to know about the world through experience.

Dark (μέλαν)

Predominance of arrangements and shapes are necessary conditions for colour formation in the descriptions of bright and red, but it becomes clear in Democritus' explanation of dark that these features alone are not sufficient for explaining colour. As in the case of bright, the initial focus on shape in the description of dark (μέλαν) things gives way to an account of the structural components associated with arrangement.

T4 Theophrastus, *de Sensibus* 74.1–6

τὸ μὲν οὖν λευκὸν ἐκ τοιούτων εἶναι σχημάτων. τὸ δὲ μέλαν ἐκ τῶν ἐναντίων, ἐκ τραχέων καὶ σκαληνῶν καὶ ἀνομοίων· οὕτω γὰρ ἂν σκιάζειν καὶ οὐκ εὐθεῖς εἶναι τοὺς πόρους οὐδ' εὐδιόδους. ἔτι δὲ τὰς ἀπορροίας νωθεῖς καὶ ταραχώδεις· διαφέρειν γάρ τι καὶ τὴν ἀπορροὴν τῷ ποιὰν εἶναι πρὸς[70] τὴν φαντασίαν, ἣν γίνεσθαι διὰ τὴν ἐναπόληψιν[71] τοῦ ἀέρος ἀλλοίαν.

Bright consists of shapes of those kinds. Dark consists of the opposite, rough, uneven, and dissimilar; for in this way they cast shadows and their pores are neither straight nor easily penetrable. Further, their effluences are sluggish and full of disturbance; for

[69] Sextus Empiricus, *M*. 7.136 = DK 68 B9.

[70] διαφέρειν […] πρὸς is usually translated 'different with regard to', but it can also mean 'different from'. See Arist. *HA* 505a21.

[71] The term ἐναπόληψις, according to a TLG search, occurs a mere 28 times in Greek and its cognate verb ἐναπολαμβάνω only slightly more frequently. In nearly all cases, ἐναπόληψις is mentioned in relation to air. Theophrastus' only other use of ἐναπόληψις is reporting Democritus' comments that the position and retention of the void spaces making a substance hard or soft is different in some respects from that which makes something heavy or light (*DS* 62.2-4).

the effluence differs qualitatively from the appearance, which is altered in quality because of the retention of air.

Theophrastus does not dwell on the differences between various textures of dark things, although the description of smooth darks in his critique suggests that such details were part of Democritus' account.[72] Terms such as τραχύς and σκαληνός stand in direct opposition to the description of bright. While these adjectives may describe particular atomic shapes, the final descriptor in the group, ἀνομοίος, cannot. Rather, ἀνομοίος signals comparison among dissimilar shapes, suggesting that even if they are not rough or uneven, an object composed of varied shapes could produce a dark appearance. It is equally likely that these terms refer to microstructures rather than to atoms themselves. An explanatory γὰρ links rough, uneven, and dissimilar with the microstructural properties of shadowing and crooked, impenetrable pores, which cannot be features of atoms. Such terms stand in direct contrast with those of brightness, which further underscores the importance of microstructural arrangement for Democritus' colours.[73]

However, unlike the account of brights, no specific correspondence between atomic shape and these arrangements is reported, and the report contains none of the rich technological and natural examples we saw in the case of bright and red. Here, there is only a general correspondence between darkness and shadows, crookedness, and impenetrability. Theophrastus may have elided fuller explanations, assuming that his reader could supply the

[72] *DS* 79.7-9: σημεῖον δέ· καὶ γὰρ αὐτὸς ταύτην φέρει τὴν πίστιν, ὅσα τῶν λείων μέλανα φαίνεται· διὰ γὰρ τὴν σύμφυσιν καὶ τὴν τάξιν ὡς τὴν αὐτὴν ἔχοντα τῷ μέλανι φαίνεσθαι τοιαῦτα. 'And there is evidence of this, for he himself gives the reason for those smooth things that appear dark: they appear thus because, thanks to their natural contact, they also have an arrangement that is the same as dark.'

[73] This correspondence between bright and dark may have led Theophrastus to assert the priority of bright over dark (*DS* 81.2-3). However, Democritus' theory neither requires nor allows for a natural priority of one colour over another, particularly because colour is among the things that are conventional rather than real. This, must be Theophrastus own Aristotelian assumption, clearly stated and easily set aside from the Democritean evidence.

necessary explanations *mutatis mutandis* from the account of brights. Instead, he records how atomic arrangement affects the effluence and air imprint responsible for vision.

Effluences, Light and Air

Ancient *testimonia* assign to Democritus a theory of vision by means of the effluences, which flow from all things and enter the eye.[74] These effluences are one-atom-thick, three-dimensional copies of an object, flowing off its surface in a constant, near-limitless stream resembling a cinematic projection. The complex mechanism by which they are imaged in the eye (*DS* 51.6-7), and their role in the formation of air imprints (*DS* 50.4-5) is the focus of the first part of Theophrastus' report of Democritus' visual theory.[75] He is our only source for the role of air imprints in Democritus' account and, like many modern scholars, he criticizes them as superfluous in an explanation of vision that already posits effluences.[76] In an attempt to explain the inclusion of air imprints, some scholars have suggested that 'the air functions as an obstacle between the eye and the objects of vision',[77] but such interpretations dismiss rather than make use of air imprints in Democritus' theory.

Recently, Rudolph has argued that air imprints are responsible for the perception of distance and perspective, due to the increasing density of the compressed and shrinking

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[74] *DS* 50. DK 68 B123 preserves Democritus' term δείκελον for this 'effluence similar in kind to the object' from which it flows; our sources refer to the effluence as an εἴδωλον or an ἀπορροή. Diogenes Laertius (9.44) sums up Democritus' theory of perception with the incredibly succinct ὁρᾶν δ' ἡμᾶς κατ' εἰδώλων ἐμπτώσεις ('we see by the impact of images'). Democritus, his predecessor Leucippus and the later Epicurean atomists often are categorized together because they theorise εἴδωλα as the cause of vision. See the testimony of Aetius (DK 67 A29 and A31); Cic. *ad Fam*. 15.16.1; Alex. *de Sens.* 24.14-21 (εἴδωλά τινα ἀπορρέοντα, 'certain images emanating'), 56.10-15 (colour as an effluence) and *de An.* 134.28-136.28.

[75] For recent, detailed discussion, see Rudolph (2011). Cf. Baldes (1975); Burkert (1977); O'Brien (1984); von Fritz (1953); Avotins (1980).

[76] *DS* 51.5-7. Cf. English (1915) pp. 218-221. Guthrie (1965) pp. 442-443 and Burkert (1977) posit varying two-theory solutions; von Fritz (1953) p. 95 n. 50 dismisses the possibility of a consistent interpretation.

[77] Lee (2005) p. 204. See also Beare (1906) pp. 26-27; Baldes (1975) and Taylor (1999) pp. 206-211, who argue that air imprints are responsible for visual distortion.

effluence as it moves towards the eye.[78] Her interpretation explains the role of the sun and air in the visual process but, as we will see, they also have an essential role in the perception of colour. After all, Theophrastus explicitly states that Democritus 'seems to describe brightness as being caused by light or something else, which is why he also gives the density of air as the cause of things appearing dark'.[79] We will return to the elliptical comment in T4 concerning the link between the effluence and the φαντασία below, and instead focus now on how the pores of an object's microstructure affects the quality and transmission of the effluence to the perceiver.

As we have seen, pores are a common feature in Democritus' account of bright and dark, which lend a dimensionality to his account. In the former, they are straight and easy to penetrate, not overlapping, and transparent.[80] In the latter, by contrast, they are crooked, not easy to penetrate, overlapping, and not easy to see through.[81] That the pores are important is clear not only because they appear frequently in the description of colour, but also because of their prominence in Theophrastus' objections to the theory (*DS* 80). Even his critical comments about shadowing, transparency, and the thickness of effluences relate to the role of pores in Democritus' account. Perhaps all of Theophrastus' concerns can be summed up thus: why does the alignment of pores matter for a theory of colour that relies on effluences, air, and light?

Commentators have failed to account adequately for the pores in their reconstructions of Democritus' thought. It cannot be the case, as von Fritz argues, that white and black arise because the pores of the object allow or hinder the emanation of effluences.[82] There is no

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[78] Rudolph (2011) pp. 76-77.

[79] *DS* 80.10-12. This correlation of colour with light and air brings Democritus much closer to the theoretical position of his contemporaries. See Rudolph (2016) for a discussion of Presocratic theories of vision from Alcmaeon to Democritus. See Sedley (1992a) and Ierodiakonou (2005) on Empedocles. See Laks (1988) on Parmenides.

[80] *DS* 73, 79-80.

[81] *DS* 74, 79-81.

[82] von Fritz (1953) pp. 97-98.

evidence that Democritus assumes that effluences come from *inside* the object, which would have to be the case if pores allowed them through. Furthermore, von Fritz seems to think that a shadow, for Democritus, is what occurs when the particles of the image are blocked, but again this assumption finds no foundation in the evidence. Baldes offers an alternative suggestion, hypothesising deflection of light as the cause of whiteness and the thickness of air as the cause of blackness.[83] Problems arise with this interpretation in part because Baldes assigns contradictory effects to light; it both compacts the air so that an imprint can form,[84] and thins that imprint for the perception of the colour white.[85] The thinning of the imprint, Baldes suggests, occurs when light penetrates the image through the gaps that represent the pores in an object. However, any void in an effluence would be filled upon contact with other atoms, so there would be no gaps in the image when it reaches the eye.[86] In the case of darkness, too, Baldes' theory runs into difficulties because he fails to explain how crookedness in an atomic structure leads to variation in the position of gaps in the images. This variation produces a build-up of air responsible for the sluggishness and disturbance associated with darkness.

I propose a different reconstruction of the evidence for the pores of objects and the importance of light and air for the perception of bright and dark. Pores are, quite simply, a passageway of void in an object. In normal daylight conditions, sunlight prepares the air for vision by condensing and moulding it (*DS* 54). If a 'bright' object is illuminated, we may speculate that it absorbs rather than deflects light, since the pores are easy to pass through (*DS* 73: μηδὲ δυσδίοδον, διαυγῆ; 80: εὐδίοπτον). Such translucency is an important element in Democritus' theory, because once light penetrates the pores, it passes back out of the object as a part of the effluence. If the object has straight pores or exhibits smoothness, the absorbed light will easily pass through, filling the gap left by the pores with light particles in

[83] Baldes (1978) pp. 94-97.

[84] Baldes (1978) pp. 89-90.

[85] Baldes (1978) pp. 96-97.

[86] See below for further discussion.

the effluence. This will be true even for objects that appear rough on the surface. In each case, the object remains shadowless.

As the effluence moves towards the eye, an air imprint takes shape, which differs in colour and consistency from both the ambient air and the object (*DS* 50.5). Theophrastus criticises Democritus for making brightness akin to transparency (*DS* 80.3-5), but the colour-contrast Democritus posits as an explanation for the image is a contrast with the colour of the air. Since 'things alike in colour are not imaged' (*DS* 54.8-9), objects that are like the colour of air are transparent. In this way, the effluence differs both from the object (because where the object has a straight pore, the effluence has light) and from the ambient air (which is transparent). If the amount of light available to pass through the pores diminishes, the object will appear darker because there is less total light. This explains why a white animal appears darker in the shadows (*DS* 80.1-2) than in broad daylight.

By contrast, if a crooked-pored object is illuminated, the light may be haphazardly absorbed, or not absorbed at all. If light illuminates a 'dark' object, its rough and jumbled arrangement may prevent light from penetrating the pores, or if light does penetrate, the overlapping or crooked pores may prevent it from leaving the object. When the effluence flows from this object, a void will represent the crooked or overshadowed pore.[87] Because the nature of the void is to yield to what is solid, as soon as the effluence makes contact with the air, it will fill these void spaces.[88] As the effluence moves through and imprints the air, the image that forms is dense and thick, due to the retention of air (*DS* 74.5-6; *DS* 80.10-12). This, in turn, produces the perception of darkness. Thus, Democritus can explain darkness as the result of both overshadowing and the thickness of air (*DS* 81.2-5). The microstructure of

[87] As Theophrastus notes (*DS* 80.9-10), it is difficult to believe that an effluence comes from void, but his desire for an explanation of how that would occur misses the point about light and air filling the void left by a pore in an object. The fact that he mentions both light and air in the very next sentence (*DS* 80.10-12), suggests that he is perhaps skimming over the connection between these three components of Democritus' account.

[88] This is one further reason to reject Baldes' (1975) suggestion that the air imprint occurs at or very near the eye, since the effluence must travel through the ambient air toward the perceiver and would, therefore, have the void of the pores filled before it reached the eye.

the object influences how the effluence interacts with light and air. Bright things let light in; dark things do not. In a sense, then, Theophrastus is right when he suggests in his critique (*DS* 81.5-6) that transparency and opacity play a central role in Democritus' account of bright and dark. This is why, for Democritus, the alignment of the pores is an essential component of his explanation of bright and dark.[89]

In addition to having an influence on the configuration of the image, the retention of air in the effluence also affects the movement of the image toward the eye in two possible ways.[90] Democritus describes dark effluences as νωθής and ταραχώδης (*DS* 74.5). These terms are almost certainly Democritus' own, since they are infrequent in Theophrastus' extant writings. νωθής signifies slowness or sluggishness,[91] which differs from the disturbing or troubling movements associated with ταραχώδης.[92] In the case of dark objects, only

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[89] *Contra* Theophrastus *DS* 80.7-9.

[90] Beare (1906) p. 32 and von Fritz (1953) p. 98 seem to assume they describe a single motion.

[91] According to a TLG search, νωθής and its cognates occurs four times in the Theophrastean corpus in the passage cited above and in reference to the slow burning of green wood (*HP* 5.9.3.6), the sluggishness of the salamander (*de Igne* 61.1), and, citing the theory of Diogenes of Apollonia, the slow wits of a child (*DS* 45.3). See also, its use of stubborn or slow animals: Hom. *Il*. 11.559, Pl. *Ap*. 30e, Arist. *HA* 503b8 and of slow-moving water: Pl., *Tim*. 86a5.

[92] The suffix –ώδης, formed from ὄζω (to smell), comes to mean 'full of' or 'like. See Smyth §833. The verb, ταράσσω, is used frequently of the tumult of a mob (Hom. *Il*. 1.579, 2.95, 7.346), the sea (Hom. *Od*. 5.291, 304; Archiloch. Fr. 105 West (quoted in Thphr. *Sign.* 45); Solon 12), an army (Hdt. 4.125, 9.51, Th. 4.25, X. *Cyr*. 2.1.27) or the mind (A. *Ag*. 1216; S. *OT* 483; E. *Hipp.* 969; Pl. *Phd*. 66a). In the Hippocratic Corpus it tends to signal the unsettled movement of the bowels (κοιλία, e.g. *Epid*. 1.1.2.18; *Prorrh.* 1.108.2; *Coac.* 10.3, 268.2), of thought (γνώμης, e.g. *Epid.* 3.2.8.7; *Prorrh.* 1.139.3); and of dreams (ὕπνος, e.g. *Coac.* 81.2, 147.1, 223.2; *Judic.* 39.2). Also of injury (κώφωσις, e.g. *Prorrh.* 1.33.1; *Coac.* 186.2; *Mul.* 1.41). Both here and in *DS* 81 ταραχώδης/ταραχή may signal distortion rather than mere disturbance, in which case Democritus may be referring to optical illusion. See Taylor (1999) p. 209 and Lee (2005) p. 204, who suggests that air is an obstacle between the eye and the object. The verbal form ταράττειν occurs at *DS* 65, where, according to Democritus, the sweet stirs up other flavours, causing them to be led astray and moistened. In addition to the passages discussed above, adjectival and verbal forms of ταραχή, in the general sense of turbulent or disturbed, are found in *Lap.* 61, *Vent.* 55.12, 362A FHS&G (175 W) and 365C FHS&G (Frg. 188 W).

ambient light, which moulds and compresses the air in preparation for receiving the air-imprint (*DS* 54), is active in the transference of the image to the eye. If we are right to suppose that the atoms of sunlight, like those of fire, are small, spherical, and capable of swift movement,[93] then the sluggishness associated with dark effluences may be a result of this relative lack of light.[94]

What difference might movement make to the perception of colour? In instances where the ambient air is full of light, like at midday on a cloudless afternoon, the slowness of the dark effluences will be negligible. But at dawn or dusk, we can imagine that the lack of light in the air will make dark objects harder to distinguish. If this suggestion is correct, air imprints may, under certain conditions, result in distorted vision, but only as an exception rather than as a rule.[95] It is not, then the air imprint *per se* that is responsible for the distortion, rather, it is the speed of the effluence that brings about distortion.[96]

Theophrastus also mentions the disturbing movement of the effluences (*DS* 74.5) and the disturbance of the eye (*DS* 81.5) in connection with the perception of darkness.[97] Such a quality finds no parallel in the *DS* and no additional factors related to the nature of the effluences, the air or light explains disturbance, which is perhaps what leads some scholars to equate it with sluggishness.[98] However, Theophrastus' summarising technique tends not to allow such redundancy. Moreover, after mentioning the disturbance of the eye in his critique,

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[93] See note 58 above.

[94] The lack of sunlight may also explain why it is not possible to see at night (*DS* 53.8-11). See Rudolph (2011).

[95] *Pace* Beare (1906) p. 27. Cf. Baldes (1975); Taylor (1999) pp. 206-211; Lee (2005) p. 204.

[96] One could hypothesise that an abundance of light particles in effluences would have the opposite effect. By making the effluence move faster, the result would be an overwhelming, sharp brightness that disturbs the eye.

[97] Baldes (1978) p. 96 suggests that the confusion of the eye mentioned at *DS* 81 arises from a constantly varying reflection in the eye.

[98] See Baldes (1978) and von Fritz (1953).

he hints at another cause of darkness, separate from opacity, but says Democritus does not make it clear.[99]

If we look to another Theophrastean treatise, however, the link between the perception of darkness and disturbance both of the object and in the eye becomes evident. In *On Dizziness* (*Vert.*), Theophrastus mentions a theory in which vision is darkened (σκοτούνται) when looking at swinging objects or rotating wheels because 'it happens that as the faculty of sight moves in a circle, it moves the inside parts irregularly and disturbs (ταράττειν) them'.[100] A similar case of internal visual disturbance also arises from looking at high, tall, and steep things, although in these cases the disturbance is due to the shaking and vibrating of overstretched sight.[101] Such explanations are consistent with what we know about Democritus' theory of vision.[102] In the first case of disturbance by rotation or swinging, external movement brings about internal movement. If this is Democritus' theory, the 'darkening' may arise due to the irregular bombardment of effluences on the eye. The

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[99] *DS* 81.5-6. Theophrastus uses a similar rhetorical move at *DS* 54.9-10 in relation to the explanation of the perception of size and distance. Rudolph (2011) provides a reconstruction of that explanation.

[100] *Vert.* 7: καί οί τάς αιώρας καί τους τροχούς θεωρούντες ή καί συμπεριφέροντες τήν όψιν ταχύ σκοτούνται· συμβαίνει γάρ κινουμένην κύκλω τήν όψιν κινεῖν τά έντός άνωμάλως καί ταράττειν. 'And those who look at swings and wheels or actually rotate their sight with them quickly suffer darkening vision; for it comes about that as their sight moves in a circle it moves the inside parts unevenly and causes disturbance.' Trans. Sharples (2003), modified. *Pace* Sharples (2003) p. 173 there is no need to translate σκοτούσθαι and its cognates as 'giddiness' here or in Hippocrates *Epid*. 1.2.6 L. (or indeed at 5.1.50.3 or 7.1.32.2) and Pl. *Prot.* 339e, *Tht.* 209e, *Resp.* 506a or 518a, where a literal translation works just as well. Cf. *Lg*. 892e, where the metaphorical language of confusion seems more apt.

[101] Theophr. *Vert.* 8: ίλιγγιώσι δέ καί οί τά υψηλά καί τά μεγάλα καί άπότομα άποβλέποντες διά τό συμβαίνειν μακράν άποτεινομένην σείεσθαι καί κραδαίνεσθαι τήν όψιν σειομένη δ' ούτως καί κινουμένη ταράττει καί κινεί τά έντός. 'Those who look at high and tall and steep things become dizzy because it happens that their sight, stretched out to a great length, is shaken and vibrates, and being shaken and moved in this way it disturbs and moves the inside parts.' Trans. Sharples (2003).

[102] Even if the theory in *Vert.* is not Democritus', Theophrastus may have had such a theory in mind when he mentions disturbance of the eye as a source for darkness in *DS* 81.

alignment of pores would be disturbed, which could produce a darkened appearance even of a bright or multi-coloured object. In the second case of shaking, vibrating or overstretched sight, the movement of visual rays could affect the regular flow of images to the eye.[103] Because such irregular bombardment would alter the alignment of the images as they entered the eye, the object may appear fuzzy or darker since the pores would be misaligned.[104] In the case of disturbance, the irregular movement of the effluence is, again, responsible for visual distortion.

To sum up, this analysis has revealed that in the case of both dark and bright, multiple explanations (roughness, overshadowing or overlapping of pores, thickness of air in an effluence and its subsequent, altered movement), far from over determining the phenomena, actually give Democritus the necessary flexibility to explain variations in structure among things that appear dark.[105] The common factor uniting these explanations is the dimensionality of the effluence, which allows for the retention of air. This equips Democritus' theory to parry all of Theophrastus' objections to the atomist account of bright and dark. If the reference to the sluggish and disturbed movement of the effluence is responsible for distorted vision, then we may find in Democritus one of the earliest theorists of the mechanics of deceptive appearances.[106]

The Appearance (φαντασία)

[103] See Rudolph (2011) for a detailed account of Democritus' visual ray.

[104] See *DS* 50 for images passing through the eye into ducts that are similar in shape to the impressions.

[105] Theophrastus may have found multiple explanations for the dark across a variety of Democritean treatises, or his epitome may have listed more than one explanation under Democritus' name. This may also explain the elliptical references to the role of disturbance in the perception of darkness.

[106] Such concerns are common in the Hellenistic period, but do not seem to have been as prominent in early philosophical discussion. However, Philoponus (*in GC* 23.1-16) appears to find the problem of the square tower appearing round in Democritus. It also appears in the Aristotelian *Problemata* (911b19-21). See Lloyd (1982) pp. 128-64. Hankinson (1996).

Let us now return to the interpretation of φαντασία in T4 (*DS* 74.5-6). The natural reading of the passage takes φαντασία as the antecedent of ἣν, meaning that the φαντασία, not the effluence, retains air.[107] However, when we examine how φαντασία is used elsewhere in the *DS*, it is not clear that it can denote something able to hold air across the sense modalities. It may just mean the subjective impression present to the perceiver during sensation.[108] That φαντασία is Democritus' own term cannot be established beyond all doubt, but we need not follow Watson and Rees, who argue that φαντασία is a term introduced in the middle dialogues of Plato.[109] Plato and Aristotle both use it in discussing the views of Democritus' fellow Abderite, Protagoras.[110] Sextus Empiricus goes further, including Democritus among the opponents of Protagoras: 'One cannot say that every φαντασία is true because this refutes itself as Democritus and Plato taught in opposing Protagoras'.[111] Watson, following Rees, dismisses this as an assimilation to later terminology, but the evidence is consistent, which

[107] Such a reading corresponds to an interpretation of Democritus' physics that reduces everything, including non-physical things like appearances, to atomic structures.

[108] See Warren (2002) pp. 193-200. It is seemingly for this reason that Beare (1906) p. 32 and Stratton (1917) p. 135 understand the ἀπορροή as the antecedent of ἣν. Taylor (1999) p. 116 suggests that it is the appearances (φαντασία) 'which are produced by the reception of impressions of different kinds made on the air'.

[109] Watson (1988) p. 1 and Rees (1971) p. 503 n. 7. See also Ross (1961) and Hamlyn (1959) who believe that Aristotle is inconsistent in his account of φαντασία, whereas Schofield (1978) maintains that φαντασία is a loosely knit family concept. Cf. Lycos (1964), Nussbaum (1978), Frede (2000) and Caston (1996).

[110] When presenting the Secret Doctrine (*Tht* 152cff.), Plato associates with Protagoras the claim that 'φαντασία and αἴσθησις are the same in the case of things that are hot and in all things of such a kind. As a person senses things, so we can say, they are for him.' Likewise, Aristotle employs φαντασία in his response to Protagoras (and his other predecessors, including Democritus) in *Metaph.* Γ.5 1010b1-3. He writes, 'concerning the truth we must maintain that not everything which appears is true; firstly because even if perception—at least of the object peculiar to the sense in question—is not false, still φαντασία is not the same as αἴσθησις. Bonitz's emendation of the text makes it clear that Protagoras thinks all perception, whether of proper sensibles or others, is true.

[111] S.E. *M.* 7.389-390.

suggests that Protagoras may have been the first to apply it to perception, and that Democritus, Plato, and Aristotle employed it after him.[112]

That Theophrastus was interested in following up some of the details of Aristotle's discussion of φαντασία is evident in the fragmentary sources, but he does not seem to have developed any positive theory about its status.[113] Indeed, a survey of Theophrastus' use of φαντασία across his extant works shows that it does not have a strongly technical Aristotelian colouring. In his botanical works, φαντασία is used in instances where he wishes to highlight how the colour or odour of a fruit or plant can be misleading by making it appear to be ripe or a particular variety, when, in fact, it is not. [114] In the *DS*, φαντασία is used exclusively in connection with Democritus, which suggests that it is not a concept Theophrastus wishes to impose on his predecessors. If it were, we would expect him to use it when discussing Empedocles, Anaxagoras or even Plato, since elsewhere he is clearly following up Aristotle's arguments in *De Anima* 3.3.[115]

Two of the four uses of φαντασία in the *DS* appear in general statements about how the atomist asserts that sensation occurs. At *DS* 63.2-4, Theophrastus reports that apart from the perception of hard, soft, heavy and light, Democritus makes the other sensations 'experiences of the sense faculty as it undergoes alteration. From this altered sense the appearance arises.'[116] Given what we know about Theophrastus' efforts to separate the

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[112] See Lee (2005) on Democritean, Platonic and Aristotelian responses to Protagoras.

[113] See Huby (1999) pp. 84-86. Watson (1988) pp. 34-37, 123. In the fragments that do survive, it seems that Theophrastus is attempting to link φαντασία more closely with the rational faculty than with sensation or the sense organ.

[114] Thphr. *CP* 2.16.5.7 and 5.1.6.6. Another sense altogether is found in his account of plants called στρύχνος at *HP* 9.11.6.6, where φαντασία describes the illusions that one may experience when one has ingested a double dose of this plant. Varied usage in Theophrastus may reflect the ambiguous meaning of the term during the late Classical and early Hellenistic periods.

[115] Huby (1999) p. 86 on FHS&G 299. Cf. Watson (1988) pp. 34-37.

[116] τῶν δὲ ἄλλων αἰσθητῶν οὐδενὸς εἶναι φύσιν, ἀλλὰ πάντα πάθη τῆς αἰσθήσεως ἀλλοιουμένης, ἐξ ἧς γίνεσθαι τὴν φαντασίαν. 'But he says that none of the other sensory objects has a nature, but that all are affections of the

φαντασία from sensation and the sense organ in his work, we would expect him to comment on the link between sensation and φαντασία here, but this never materialises.

φαντασία appears twice in *DS* 64, in relation to Democritus' theory of sensation and human experience. Theophrastus asserts that Democritus makes humans his reference point for the φαντασία of flavours (*DS* 64.6).[117] He further stipulates that Democritus' general view concerning the perceptible objects (τῶν αἰσθητῶν) is that 'we ourselves change our judgement according to our experiences and our ages; hence it is also obvious that one's disposition is causally responsible for the appearance.'[118] In these passages, the φαντασία is the product of the perceptual process, arising from the change brought about in the perceiver by the alterations that occur during perception.

Each of these uses of φαντασία make clear that it is a term used in relation to the divergence of perceptual experiences at the inter-species, intra-species, and intra-personal

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sense faculty as it undergoes alteration. From this [altered sense] the appearance arises.' Cf. Arist. *de An.* 3.3 and *Metaph*. Γ.5-6. See Caston (1996) for discussion.

[117] This use suggests that Democritus is referring to the impression we have about the way a thing tastes or looks to us as human beings. This comes closer to the Hellenistic way of employing the term than any typical use found in Plato or Aristotle, with the possible exception of *Tht.* 152c. The Epicurean φαντασία, in principle, could reflect Aristotle's physiological explanation of the term as Watson (1988) p. 38 suggests. However, it seems at least as likely that Epicurus' treatment of vision and φαντασία (*Ep. Hdt.* 49-50) relies on Democritus as on Aristotle, especially since the description of the process of vision is so similar to Democritus' own (*DS* 50-54).

[118] ἔτι δ' αὐτοὺς μεταβάλλειν τῇ κρίσει29 κατὰ τὰ πάθη καὶ τὰς ἡλικίας· ᾗ καὶ φανερόν ὡς ἡ διάθεσις αἰτία τῆς φαντασίας. ἁπλῶς μὲν οὖν περὶ τῶν αἰσθητῶν οὕτω δεῖν ὑπολαμβάνειν. οὐ μὴν ἀλλ' ὥσπερ καὶ τὰ ἄλλα καὶ ταῦτα ἀνατίθησι τοῖς σχήμασι· πλὴν οὐχ ἁπάντων ἀποδίδωσι τὰς μορφάς, ἀλλὰ μᾶλλον τῶν χυλῶν καὶ τῶν χρωμάτων καὶ τούτων ἀκριβέστερον διορίζει τὰ περὶ τοὺς χυλοὺς ἀναφέρων τὴν φαντασίαν πρὸς ἄνθρωπον. 'Furthermore, we ourselves change our judgement according to our experiences and our ages; hence it is also obvious that one's disposition is causally responsible for the appearance. This then, he says, is the general view one should take concerning the perceptible objects. Nevertheless, just as with the other sensibles, these too he refers to shapes. Except he does not explain the forms of all, but he explains more about the forms of flavours and colours, and of these he differentiates more precisely the topic of flavours, using man as his reference point for their appearance.'

levels. Moreover, in T4, it is not merely a variation but a distortion in the perception of sluggish or disordered images that the φαντασία helps to explain.[119] This use suggests that sensory divergence and the differences of opinion that arise from it are a central concern of Democritus. Indeed, the components of Democritus' account of vision and colour seem aimed entirely at accounting for divergence, not merely explaining it away.

That Democritus used the common verb φαίνεσθαι in sensory contexts need hardly be doubted. But the above evidence suggests, in addition, that he and his older contemporary Protagoras, were already using the corresponding abstract noun φαντασία as a more or less technical term in the context of sense-perception. Thus, it is likely that the term φαντασία is Democritus' own rather than an assimilation of Democritean physiological notions to later terminology. From these uses, φαντασία seems to express the representational content of sense perception, which can admit variation and under certain conditions, error. Indeed, Democritus may have introduced the concept into his own theory in order to explain the variations and potential mistakes that can arise in perception.[120]

One further use of φαίνεσθαι in Democritus' account of the colour purple is worth exploring in this context. Theophrastus reports that 'purple comes from bright, dark and red, having the largest portion of red, a small one of dark, and a medium one of bright. That is why it also appears pleasant to the sense faculty. That dark and red are present in it is clear to the eye; the luminosity and transparency are signs of the presence of bright, for bright

[119] Error formation is Aristotle's principle concern when he introduces the notion of φαντασία at *de An.* 3.3, where he is taking particular aim at theorists who, according to Aristotle, explain perception as like-to-like and who hold that thinking and perceiving are the same. See Caston (1996). Although not mentioned by name, Democritus seems to be Aristotle's target when he mentions Homer in this section, on which see Lee (2005) pp. 146-148. Elsewhere Aristotle and Theophrastus are explicit about Democritus' place among the categories of theorists Aristotle criticises here.

[120] The verb φαίνεσθαι appears twelve times in the Democritean section of the *DS*, predominantly in discussions of the divergence of sensory experience (*DS* 63, 69, 70, 79), distortion (*DS* 80) or pleasure (*DS* 77).

produces these effects'.[121] While we can extrapolate the microstructural components that result in purple from this description,[122] proportionality is the key factor in Democritus' explanation of the colour's pleasantness.[123] Aesthetic considerations feature also in the report of the metallic colours, where the admixture of green produces the most beautiful colour.[124] One may read these examples as evidence of an atomistic explanation even for aesthetic considerations, such as pleasantness and beauty. However, it seems more likely, given the use

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[121] *DS* 77.1-5: τὸ δὲ πορφυροῦν ἐκ λευκοῦ καὶ μέλανος καὶ ἐρυθροῦ, πλείστην μὲν μοῖραν ἔχοντος τοῦ ἐρυθροῦ, μικρὰν57 δὲ τοῦ μέλανος, μέσην δὲ τοῦ λευκοῦ· διὸ καὶ ἡδὺ φαίνεσθαι πρὸς τὴν αἴσθησιν. ὅτι μὲν οὖν τὸ μέλαν καὶ τὸ ἐρυθρὸν αὐτῷ ἐνυπάρχει, φανερὸν εἶναι τῇ ὄψει, διότι δὲ τὸ λευκόν, τὸ λαμπρὸν καὶ διαυγὲς σημαίνειν· ταῦτα γὰρ ποιεῖν τὸ λευκόν. For discussions of πορφυροῦν see Irwin (1974); Edgeworth (1979); Stulz (1990); Longo (1998); Brecoulaki (2014).

[122] For example, purple things are likely to contain large, dense aggregations of atoms that are in straight-pored arrangements with few crooked or rough structures that might cause air to be retained in the effluence. On the phenomenal level, Struycken (2003) pp. 286-287 suggests that the formation of this colour can be likened the description of sunrise and sunset in Arist. *Col.* 792a15-20. It is, however, equally likely that Democritus is referring to the murex dyeing process. The dye alternates between dark-blackish and reddish colours, according to Plin. *Nat.* 9.62.133, which may be why Democritus calls the presence of these two colours 'clear to the eye'. The evidence for murex dyeing in the Mediterranean is extensive, particularly in settlements of Phoenician origin, such as Abdera, where recent excavations have uncovered murex-processing installations. See Graham (1992) and Kalaitzaki et al. (2017) pp. 109-110.

[123] Reinhold (1970) notes that purple is downgraded due to anti-Persian sentiment from c. 490 to 420 BCE, particularly in Athens. However, there is strong evidence that Abdera was allied to the Persians (Hdt. 6.46-47), and according to D.L. 9.35 Democritus studied in Persia. By the Hellenistic period, purple had once again regained its popularity, particularly after Alexander adopted the colour on defeating Darius in 330 BCE.

[124] *DS* 76.3-9: 'The golden, copper and all such colours are from the bright and red. For, on the one hand they have the luminous from the bright, and ruddiness from the red. For the red falls into the void spaces of the bright because of the mixture. But if green is added to these, the most beautiful colour results. But the admixtures of green must be small. For, it is not possible for them to be large given that this is how bright and red are composed. The colours will differ by receiving more or less.' That gold is the most beautiful colour was as undisputed as that honey is the sweetest flavour (Pl. *Hp. Ma.* 289e). See Sassi (1978) p. 144, Craddock et al. (1988) and Ramage et al. (2000). It is clear from the archaeological record that gold production flourished at Abdera from an early date. See Graham (1992).

of φαίνεσθαι, that this too is a case of sensory divergence for Democritus, since perceivers may disagree about what is most beautiful or pleasant. The preponderance of the evidence, then, is in favour of Democritus' use of φαντασία and its cognates in contexts where sensory divergence is at issue.

The larger point of T4 is that the effluence as it comes off the object and the φαντασία that is formed as the effluence moves through the air are qualitatively different and ontologically distinct. In other words, the object's effluence and the φαντασία experienced by the viewer are not only not exactly the same, but also cannot be the same because the environment fundamentally alters the effluence during the visual process. We may infer from the evidence of the *DS* an account that makes the sensibles (αἰσθητά) and the appearances (φαντασίαι) two distinct effects of the same process, which arise simultaneously and are causally unrelated.[125] The φαντασία arises separate from the quality in the case of colour, and there is no clear evidence that the qualities themselves are causally efficacious in the general description at *DS* 63.[126] This means that the object of vision is never an exact, unmediated replica of the object itself, which is why Democritus chooses to liken this process to a wax impression.[127] We cannot have access to the object-as-it-is-in-itself because its effluence mixes up with atoms of light and air in order to take on colour. This is why colour is conventional: we see only what arises when the effluence is mediated by our environment and our own visual process. Thus, in its most basic sense, the convention consists in taking 'red' to denote some actual property of an object, rather than realising that colour is a contingent construct of multiple factors in the process of vision itself. In this way Democritus' sensible qualities are removed from those things that exist in reality because they have no causal efficacy in the perceptual process. Thus, Democritus is not so much an

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[125] Cf. Pl. *Tht*. 156a, 159c-e.

[126] For dark-black things, this is because the effluence retains air, whereas the effluences of bright things retain light in place of their pores. Likewise, in the case of red, green and the compound colours. The distinction between the effluence and the φαντασία is clearer in the case of dark than bright, which may be why Theophrastus reports the distinction here.

[127] *DS* 51-52, 54.

eliminative materialist or even a subjectivist as an epiphenomenalist, who believes that although sensible properties seem to exist in the world around us, they are really just by-products of a physical interaction taking place when atoms from object, environment, and perceiver mingle in our subjective experience.

When we turn to the epistemological concerns that arise from the conventionality of colour, we find some basis for empirical knowledge. Via the effluence that enters the perceiver's eye (*DS* 51), we do have some access to the components of the object itself, even if they are mediated by the environment and visual process. Thus, when in his *Canons*, Democritus asserts that the canonical list of five senses as a means of knowing are 'in the dark' (σκοτίη), the metaphor is apt. There is a point beyond which the senses cannot go in their analysis of experience, precisely because sensation is always mediated. In the case of vision, it is the environmental factors of light and air that making the resulting image ontologically distinct from the effluence. It is, then, the work of the so-called 'pure' or 'genuine' (γνησίη) cognition to undertake a finer analysis.[128] It is reason that strips away the environmental factors that contribute to our sensations in order to determine the underlying structure of reality. It is also clear from the foregoing analysis that Democritus does not think that we are generally misled by the senses, rather, the point is that they do not offer a 'pure' understanding.

Democritus attempts to establish a basis for empirical knowledge that nonetheless takes account of perceptual variability and visual distortion. In the case of colour, he does this by utilising the principle of predominance[129] in conjunction with multiple explanations for a single phenomenon. Such an explanatory framework allows him to hypothesise the microstructural properties of an object and their relation to the environment as distinct from the representational content of perception (φαντασία), from which judgements arise. This gives Democritus a unique approach not just to colour formation, but to how human beings come to know the world around them.

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[128] See Sedley (1992b).

[129] Predominance also features in the explanation of flavour at *DS* 67. See Rudolph (2018b).

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