HEAVY AND LIGHT IN DEMOCRITUS AND ARISTOTLE: TWO CONCEPTIONS OF CHANGE AND IDENTITY

I

ARISTOTLE and Theophrastus are the two major sources for our knowledge of the atomist theory of weight.[1]

In the *De generatione et corruptione* Aristotle argues that one atom may be hotter than another and that therefore the atoms cannot be impassible, since an atom which is only slightly hot could not fail to be acted upon by an atom that was very much hotter (i 8 325b36–326a14, esp. 326a6–12 = in part DK 68A60). The premiss to the argument Aristotle derives in part from a comparison with weight. It would be ridiculous, he claims, to suppose that hotness and coldness belong to the atoms, but that heaviness and lightness, hardness and softness do not belong to them (326a6–8). And in fact, he continues, Democritus does claim (*καίτοι . . . γε . . . φησίν*) that each of the 'indivisibles' is *βαρύτερον . . . κατὰ τὴν ὑπεροχήν* (a9–10). Aristotle has already supposed that one kind of atom, a round atom, may be accounted as hot (a3–5). The use of the comparative for weight (*βαρύτερον*) Aristotle now takes to justify the use of the comparative for heat (*θερμότερον* a10–11): from this there follows the argument that the atoms cannot be impassible.

The meaning of the expression that I have quoted (*βαρύτερον κατὰ τὴν ὑπεροχήν*) has been much debated. Cherniss takes the point to be that each atom has relative weight, and from this, and from another passage, he concludes that Democritus 'did not attribute *real* weight to the atoms' (my italics).[2] The connection of thought in Cherniss seems to me obscure; but there is no need to press the point, since the premiss is false.

The meaning of *βαρύτερον* as 'relatively heavy' Cherniss seeks to derive, in part, from *τὸ κουφότερον* in a passage in the *De caelo* where Aristotle argues that 'what is absolutely light is always lighter, but what is lighter (*τὸ κουφότερον*) is not always light, since among things that have heaviness one thing may be lighter than another, as water is lighter than earth' (iv 2, 309b5–8). Both Cherniss and Professor Guthrie take *τὸ κουφότερον* to mean here 'what is relatively light'.[3] But from what Aristotle says it isc lear that that expression must embrace *both* what is relatively light *and* what is absolutely so. 'What is lighter is not always light'. *Sometimes it is:* fire is lighter than the other elements, and is light *absolutely*. But not always: water is lighter than earth, and is light in a relative sense.

Τὸ κουφότερον does not mean therefore *only* 'what is relatively light', and *βαρύτερον* need not therefore, and I believe does not, mean what is relatively heavy. On the contrary, throughout his criticism of Democritus in the fourth book of the *De caelo* Aristotle consistently makes two points. First, the atoms may themselves be treated as being heavy absolutely, in so far as they are carried always downwards. Secondly, composite bodies, i.e. bodies derived from the atoms, cannot therefore produce those differences in weight

[1] This article summarises, except for the final section, a much longer study of which the first volume will be published soon in *Philosophia Antiqua*. The pages on Democritus were read to a session of the Third International Symposium on Ancient Philosophy held at Toledo in the summer of 1974 and presided over by Professor W. J. Verdenius. I am particularly grateful for the criticisms made at the conference by Professor Verdenius and Mr Peter Bicknell. I am also most grateful for their criticisms to Mrs K. M. Burnett, Mme F. Zaslawski and Dr S. V. Keeling. The whole paper has also benefited greatly from a series of lucid and very useful criticisms made by Dr G. E. R. Lloyd.

I would emphasise that in this paper I have deliberately set out to present an overall view of a wide range of evidence, consciously leaving aside many of the difficulties which the interpretation of each piece of evidence has given rise to in the past. There is a much more detailed analysis in my longer study of the subject: meanwhile, the simplified treatment of the present version is, I hope, justified by the attempt to provide in a short space a single view of a complex subject which has not hitherto been treated as a whole.

[2] H. F. Cherniss, *Aristotle's criticism of Presocratic philosophy* (Baltimore, 1935) 96–100, 209–13, see esp. 211 n. 253 and 97 n. 412.

[3] W. K. C. Guthrie, *De caelo* Loeb edn (1939).

(differences between heavy and light, and differences between absolute and relative weight) which Aristotle holds to characterise the four cosmic elements.

Now a body which is heavy absolutely, in Aristotle's own theory, can never be light or lighter, but it can be more heavy or less so, depending upon its size and on its speed of fall. That, I suggest, is roughly the implication of the comparative in the *De generatione et corruptione*. Each atom, according to Democritus, will be more heavy or less so. Therefore, Aristotle argues, a spherical atom, which is hot, must be in some way more hot or less so. But in that case a tepid atom could not fail to be affected by a very hot one: and in that case the atoms cannot be impassible, as Democritus' theory, according to Aristotle, would require them to be.

In this argument the ramifications of Aristotle's perversions of Democritus' system are fascinating, but they do not, I think, whittle away the positive assertion (note *φησίν*, 326a9) that each atom is more heavy or less so 'according to its preponderance' (*κατὰ τὴν ὑπεροχήν*).

II

What then is the meaning of *ὑπεροχή*?

In the *De caelo* Aristotle contrasts Plato and Democritus on the ground that in Plato's system the larger body is invariably the heavier, while Democritus is able to explain how it is that the larger body is sometimes the lighter. In the course of this criticism, Aristotle distinguishes primary and indivisible particles which are surfaces from primary and indivisible particles which are solids. The Platonists, Aristotle claims, are absurd in supposing that from primary and indivisible particles which are surfaces there can be built up bodies that have weight, where the larger is the heavier. The Atomists, whose primary and indivisible particles are solids, are more nearly justified in claiming that the larger of these is the heavier (*τὸ μεῖζον εἶναι βαρύτερον αὐτῶν*); while in the case of compound bodies (*τῶν δὲ συνθέτων*) the admission of void is able to explain why the larger body may be the lighter (iv 2, 308b28–309a11 = in part DK 68A60).

Cherniss and now Guthrie suppose that *αὐτῶν*, in the expression I quoted, means compound bodies.[4] But this ruins the antithesis: *τῶν δὲ συνθέτων*. This antithesis, and the sequence of the argument more generally, makes it clear, or so it seems to me, that *αὐτῶν* are 'the primary and indivisible particles', which for these thinkers are solids, namely atoms.

Aristotle's argument is two-fold. On the level of the atoms, Democritus, since he adopts solids and not surfaces as the primary particles, has some justification for adopting the necessary correlation of size and weight, which Plato also is committed to in his theory of bodies that are formed from the triangles. On the other hand, Democritus escapes from this naïve Platonic equivocation of weight and size by using void to explain how the larger compound body can be the lighter.

This argument, it seems to me, precludes the interpretation of *αὐτῶν* as compound bodies. For if *αὐτῶν* were compound bodies then on the atomist theory they would have to be bodies composed of atoms and void. But Aristotle's present critique of the atomic theory is designed precisely to show that the Atomists' admission of void enables them to *escape* from the Platonic dilemma, where the larger body is invariably the heavier. The introduction of compound bodies, and so of void, in the account of bodies where the larger is always the heavier (309a1–2) would make it difficult, if not impossible, in the continuation of the argument (*τῶν δὲ συνθέτων* a2 ff.), to present void as the mechanism which enables the Atomists to escape from this dilemma, and to explain how it is that the larger body is *not* always the heavier.

I conclude therefore that the bodies which are larger and heavier are the atoms. On this interpretation, the two passages that I have considered so far complement each other.

[4] Cherniss, *ACP* 211 n. 253. Guthrie, *History* ii 403 n. 2: the reference to Cherniss in Guthrie's *History* should be corrected to conform to the reference that I have given.

From the *De generatione et corruptione* we learn that the atoms are 'more heavy ⟨or less so⟩ according to their preponderance'. From the *De caelo* we learn that this 'preponderance' is a preponderance of size: the larger an atom is, the heavier it will be.

III

This conclusion is, I believe, confirmed by Theophrastus' statement, in the *De sensibus*, that if each atom were taken on its own then even if one atom differed in shape from another its weight would be dependent upon its size, whereas in the case of mixed bodies the one which has more void is the lighter. (Cap. 61 = DK 68A135. The central sentence runs: *εἰ γὰρ διακριθείη καθ' ἓν ἕκαστον, εἰ καὶ κατὰ σχῆμα διαφέροι* [*διαφέρει*], *σταθμὸν ἂν ἐπὶ μεγέθει τὴν φύσιν ἔχειν. διακριθείη* Mullach, Diels; *διακριθῇ* PF. *καθ'ἓν* Diels; *ἔνθεν* PF. *διαφέρει* om. codex Vossianus.)

I have given the traditional rendering of the passage. McDiarmid, in work preparatory to an edition of the *De sensibus*, emends the passage to read that if each atom 'when separated according to shape differs in weight, it differs in size' (*εἰ γὰρ διακριθὲν ἓν ἕκαστον κατὰ σχῆμα διαφέρει σταθμῷ, τῷ μεγέθει διαφέρειν*).[5] There are difficulties in the transmission of the text, but McDiarmid's main argument is ideological. If the atoms differ in size *and* shape, he argues, then no conclusion can be drawn as to the relation between size and weight; for weight might as well be dependent upon shape as upon size. If weight is to be related to size, then the atoms which are compared, he argues, must have the *same* shape, and he re-writes the passage accordingly.

But the argument is false. McDiarmid thinks that the atoms which are compared must be the *same* in shape and must *differ* from each other at once in size and in weight. But we can as well argue from atoms that *differ* in shape and are the *same* as each other in size and weight: in *either* case, weight is seen to be dependent upon size. In the preceding sentences, Theophrastus has told us that the atoms differ in size and shape. He then tells us that Democritus 'defines heavy and light by size'. Obviously, if one atom has the same shape and the same size as another, then it will have the same weight. Theophrastus' point I take to be that *even if* one atom differs in shape from another (*εἰ καὶ κατὰ σχῆμα διαφέρει* or *διαφέροι*) it will have the same weight if it has the same size.

Thus the evidence of Theophrastus is at one with that of Aristotle.

1. In the *De generatione et corruptione*, 'each atom is more heavy ⟨or less so⟩ according to its preponderance'.
2. In the *De caelo*, 'the larger an atom is, the heavier it is'.
3. In the *De sensibus*, 'Democritus distinguishes heavy and light by size: if each atom is taken on its own, then even if it differs from another in shape, its weight is dependent upon its size'.

IV

It is true that, outside the texts I have quoted, Aristotle does not list weight, or differences in weight, as a property of the atoms. Indeed in the *Metaphysics* he even writes that the atoms are distinguished 'only' by their shape, position and arrangement (A 4, 985b10–19, *μόνον* b16 = DK 67A6), while in the *De generatione et corruptione* he writes that the ⟨individual⟩ atoms differ 'only' in their shape (i 8, 325b17–19, *μόνον* b18, *cf.* 326a14–17, not in DK).

But difference of size is also usually missing from Aristotle's list of the characters by which the atoms are distinguished. (*Phys.* iii 4, 203a33–b2 = DK 68A41 is the exception, in the extant works: contrast the passages quoted at DK 67A6, A9 and 68A45, also *Met. H* 2,

[5] J. B. McDiarmid, 'Theophrastus *De sensibus*', *Classical philology* 55 (1960) 28–30. 61–62: Democritus' theory of weight'

1042b11–15 and *De gen. et corr.* i 2, 315b33–316a1, not in DK.) And yet no one, presumably, would claim that the atoms did not therefore differ in size, for differences of size are specifically included in the description of the atoms which Simplicius transcribes from Aristotle's lost monograph on Democritus (*fr.* 208 Rose = DK 68A37: κατὰ μέγεθος διαφοράς). The omission of weight, as of size, from the formulae in the *Metaphysics* and in the *De generatione et corruptione* points only to the subordinate importance of either character in the atomist philosophy, and not necessarily to the absence of either of them.

As it is, the principal opposition to the evidence I have quoted lies not in Aristotle's silence on the question of weight, outside the texts I have analysed, but in a pair of passages in Aetius. In the earlier passage (i 3.18 = in part DK 68A47) Epicurus 'added' weight to size and shape as a ⟨primary⟩ character of atomic substance. This is perhaps true enough in the light of the evident subordination of weight to size in the passages I have quoted. In the later passage (i 12.6 = DK 68A47) it is stated explicitly that the atoms 'have no weight but move by bouncing off one another in the infinite' (i.e. in the void).

There is seemingly a straight conflict between this passage (I leave aside for a moment a similar conclusion in Alexander) and the passages I have quoted from Theophrastus and from Aristotle. The usual reaction, dating from Burnet, and continuing in the writings of Professor Guthrie and Professor Kirk, has been to attempt a compromise.[6] What Aetius writes will be true of atoms that are 'floating freely' in the void (Professor Guthrie's expression). What Aristotle and Theophrastus say will be true only of atoms that are caught into a cosmic vortex, where larger and heavier atoms accumulate at the centre while smaller and lighter atoms are driven to the periphery.

The immediate difficulty in this is that if the information which Aetius preserves is genuine then its most likely source will be the writings of Aristotle and Theophrastus. But in the *De sensibus* Theophrastus writes specifically of an individual atom (εἰ γὰρ διακριθείη καθ' ἓν ἕκαστον). In the *De caelo*, also, Aristotle is not at this stage writing of the inability of the atoms to account for the stratification of visible elements in the cosmos: he too is writing of the atoms as primary particles. Neither the context of the *De caelo* nor that of the *De generatione et corruptione* easily allows the qualification that the weight of atoms is manifested only within the formation of a cosmos.

Perhaps that qualification was contained in writings that are lost to us, but that were known to the author of this extract in the *Placita:* more, or all, of Theophrastus' *Physicorum opiniones*, perhaps even a copy of Aristotle's lost treatise 'On Democritus'.

But this possibility is, I think, left very doubtful by one further circumstance. A writer later than Aetius, who also had access to some at least of the writings of Theophrastus and of Aristotle that are lost to us, also writes of the theory of weight belonging to Democritus (or in a conventionally equivalent phrase to 'the Democriteans', οἱ περὶ Δημόκριτον): in this context there is no mention of the action of a vortex, and yet the atoms are described as 'moving through the void in accordance with their weight'. The writer is one of the more intelligent and certainly one of the most learned scholars of later pagan antiquity: Simplicius (*Phys.* 1318.30–1319.5 = in part DK 68A58).

Can we believe then that Aetius preserves authentic information on Democritus, of which there is no sign in the extant writings of Aristotle and Theophrastus, and which is denied by Simplicius? On purely doxographical grounds, the answer is likely to be: no.

One other author in antiquity writes explicitly of Democritus' atoms as being without weight. Alexander says that 'the parts of the atoms that are conceptually distinguishable' (τὰ ἐπινοούμενα ταῖς ἀτόμοις... μέρη) are 'weightless' (ἀβαρῆ, *Met.* 36.21–8 = in part DK 67A6). This evidence was rightly recognised as unhistorical by Zeller.[7] The idea that there were 'parts' of atoms Simplicius tells us was introduced by Epicurus in answer to the criticism of Aristotle (*Phys.* 925.13–22, cf. *Ep. ad Her.* 59, especially τῇ διὰ λόγου θεωρίᾳ). Alexander has confused Democritus' atoms and Platonic 'surfaces' (his reference to the 'third book of

[6] J. Burnet, *Early Greek philosophy* 4th edn (London, 1930) 341–7. G. S. Kirk, *The Presocratic philosophers* (Cambridge, 1957) 414–16. Guthrie, *History* ii 400–4.

[7] E. Zeller, *Die Philosophie der Griechen* i 2 ed. W. Nestle (Leipzig, 1920) 1068 n. 1, *cf.* 1076–99.

the *De caelo*', 36.28, answers to *De caelo* iii 1, 299b14–15, where Plato, not Democritus, is the target of Aristotle's criticism). Nonetheless the process of thought which has led Alexander to his conclusion is revealing. The conclusion that the parts of atoms are without weight is presented as parallel to the conclusion that the atoms have no cause of natural movement (note πόθεν . . . οὐδὲ γὰρ τὸ πόθεν . . ., 36.22 and 25).

Has the same association of ideas affected Aetius? In the preceding entry in the *Placita* (i 12.5, not in DK) we find that in Epicurus' system the atoms move downwards, when they are not affected by the *clinamen* or by their mutual collisions and entanglements. Has the argument in Aetius perhaps been that *because* for Democritus the atoms do not move downwards in the void, *therefore* they can have no weight?

Aetius would not be alone in his assumption. 'We may here pause to consider what weight means', writes Professor Kirk. But he does not pause for long. His answer (whether he is aware of it or not) echoes Burnet, who echoes Brieger, who echoes Dyroff, who echoes Zeller.[8] Weight, says Professor Kirk, 'means a tendency to move consistently in a certain direction, what we call "downwards", and a resistance to "upward" movement'. Professor Kirk's formulation, however obvious it may seem to a post-Newtonian mind, is barely adequate for Plato, and it is plainly defective as an account of what Aristotle thought. Is it then likely to be true for thinkers of the fifth century, about whom we know so much less?

I suspect not. To explore the question would take too long here. But note, for example, that according to Theophrastus heavy and light in the fifth century were attached not only to 'movements up and down', but no less to differences of density (*De sens.* 59 = DK 68A135, τοῖς αὐτοῖς refers to 'dense' and 'rare', μανὸν καὶ λεπτόν . . . πυκνὸν καὶ παχύ). No doubt differences of density will not apply to the differences in weight between individual atoms. But they would apply to groups or agglomerations of atoms. This therefore is perhaps the context for the final sentence in Theophrastus' account of Democritus: 'in other places he says that what is light is simply what is fine' (*De sens.* 62, λεπτόν = DK 68A135).

But what of the individual atoms? For the individual atoms, how else could weight be expressed, if not by movement ' "downwards", and a resistance to "upward" movement'? There is at least one possibility. Plutarch, whose first-hand knowledge of the Presocratics is far from negligible, explicitly distinguishes Plato's theory from that of the 'wise men and intellectuals of old', for whom the elements were characterised not by ⟨their movements to different⟩ 'places', but by the 'powers' appropriate to 'heavenly' and 'earthly' bodies (*De prim. frig.* 955B–C: Plato is not named, but ὥσπερ ἐπὶ ζυγοῦ is a clear enough reference to *Tim.* 63B–D). The 'powers' include 'quick' and 'light' (ταχέα, κοῦφα) for the 'heavenly' bodies, and 'slow' for the 'earthly' bodies. It is possible, it seems to me, that this alignment of weight and speed may be a clue to the 'meaning', or to the expression, of weight in pre-Platonic writers, and specifically in Democritus: whether as a result of differences in force of impact, or whether as a direct result of their size and their weight, smaller and lighter atoms move more quickly in the void, larger and heavier atoms move more slowly, in either case quite independently of the *direction* of their movement.

Note that I claim this only as a possibility. For my point is initially to offer a conceptual alternative to the supposition, shared it would seem by both ancient and modern writers, that if the atoms do not 'fall' in the void therefore they can have no weight. My point is that if we are to 'pause to consider what weight means' *for the Presocratics* then we need to consider the possibility that before Aristotle movement in a specific direction was *not* the only criterion or expression of weight, and that differences of density (for bodies compounded of atoms and void) and differences in speed of movement (for the individual atoms) may have been no less significant as manifestations, or as the 'meaning', of weight.

This possibility would enable us to adopt the testimony of both Aristotle and Theophrastus that the ⟨individual⟩ atoms differ in weight according to their size. We shall

[8] Kirk, *Pres.* 415. Burnet, *EGP* 345 n. 1, *cf.* 343 n. 3. A. Brieger, 'Die Urbewegung der Demokritischen Atome', *Philologus* 63 n. F. 17 (1904) 584–96, see esp. 586, cf. *Die Urbewegung der Atome und die Weltentstehung bei Leucipp und Demokrit* (Gymnasialprogramm, Halle A/S, 1884). A. Dyroff, *Demokritstudien* (Leipzig, 1899) 31–9. Zeller, i 2, 1084 = 5th edn i 2 (1892) 876.

not have to conclude that this is true only of atoms that are caught into the beginnings of a cosmos, and that outside a cosmos the atoms are 'floating' in the void, as Professor Guthrie supposes. On the other hand the alternative will not be to suppose that the atoms 'fall' in the void, as the atoms of Epicurus were to do. In the void the atoms are 'at war' (στασιάζειν). They 'fall *upon*' or 'attack' each other (ἐμπίπτειν). They do so, because of 'their unlikeness and the other differences between them', differences of shape and differences of size. The voice is that of Aristotle (*fr.* 208) recorded by Simplicius (*De caelo* 294.33–295.24 = DK 68A37). This is the most nearly authentic account that we have of the movement of atoms in the void. In this account, it is easy to see how differences in speed and differences in force of impact *could* have occurred as a result of differences in size, and in weight.

V

The more elaborate of Plato's two accounts of weight in the *Timaeus* occurs in his analysis of the *pathemata*, the affections which are produced upon our bodies by the primary particles, constituted from triangles, and which if they reach to the seat of consciousness, the *phronimon*, are experienced as sensations.

The *pathemata* of heavy and light are described as follows. If someone were to stand at the edge of the universe, or more strictly if he were to stand at the interface between fire and air, and were to place different quantities of fire in the sides of a balance, and were then to lift the balance into the 'alien air', the larger quantity of fire would offer the greater resistance, and it would therefore be reckoned as the heavier. Just the same happens when we weigh earthy substances on earth: the larger quantity is the more difficult to move, and is therefore the heavier (63A6–D4).

This much, I think, is unambiguous. More tricky is the sentence which follows. Earth and fire occupy opposite positions at the centre and at the circumference of the cosmos. Therefore, Plato explains, 'what is light in one place is the opposite of what is light in the opposite place', and what is heavy, down or up in the one place is the opposite of what is heavy, down or up in the opposite place (63D4–E3).

Taylor, who is only elaborating on the interpretation of the great French commentator Thomas-Henri Martin, takes this to mean that 'what is light in one place', namely a small quantity of fire at the circumference, will be the opposite of 'what is light in the opposite place', namely a *large* quantity of fire measured at the centre. The converse is then true of earth: a small quantity of earth is light at the centre and is the opposite of a *large* quantity of earth which is light at the circumference.[9] Taylor's illustration of people throwing boulders and stones off the edges of the cosmos is perpetuated in the introduction to the Budé edition of the *De caelo*, where we are told that an observer situated in the region of fire will there see earth 'monter d'elle-même au-dessus de sa tête pour regagner le centre de l'univers'.[10]

But note first that the notion of a larger quantity of fire, measured at the centre, being lighter than a smaller quantity is an Aristotelean assumption, and that in the passage that I have already quoted from the *De caelo* (iv 2, 308b28–309a11) Aristotle criticises Plato precisely for *failing* to share this assumption, and for being *unable* to explain how the larger body can be the lighter. (Regretfully I leave aside the ramifications of Aristotle's criticism, fascinating but complicated.) Note secondly that Plato himself says nothing explicitly of fire being measured at the centre or of earth being measured at the circumference. All that Plato says is that 'what is light in one place is the opposite of what is light in the opposite place'. This is ambiguous. Taylor leaps to the conclusion that the opposition lies between a larger and a smaller quantity of fire. But taken in itself the sentence could equally well be read simply as a summary of the *two* preceding examples: 'what is light in one place', a small quantity of fire measured at the circumference, is the opposite of 'what is light in the opposite place', a small quantity of *earth* (not a *large* quantity of fire) measured at the centre.

[9] A. E. Taylor, *A commentary on Plato's 'Timaeus'* (Oxford, 1928) 440–4. T.-H. Martin, *Études sur le Timée de Platon* ii (Paris, 1841) 279–80.

[10] P. Moraux (1965) cxlvii.

Not only is this a possible meaning of the sentence. It must be the true meaning. For in the sentence which follows Plato tells us that there is one thing to bear always in mind, namely that 'the journey of an element towards its kindred makes the body which is carried thither heavy, and the direction in which it is carried downward' (63E3–7). If therefore we are to imagine fire as somehow measured at the centre, even though Plato himself says nothing explicitly of this eventuality, then the larger quantity will presumably move towards its like with greater force than a smaller quantity, and according to Plato's own final rule we must therefore call the larger quantity heavy, not light, as Taylor supposes, and as it would be in Aristotle's own theory. I propose that *if* fire is to be measured at the centre then in both cases, fire measured at the centre and fire measured at the circumference, the larger quantity will be the heavier.

It is true that on this interpretation it will follow that 'up' and 'down' have to be measured, not according to the everyday assumption whereby 'upwards' means from earth to sky (i.e. outwards from the centre), but according to the location of the element. Fire, at the centre, will be travelling *downwards* when it moves towards its parent body (ἡ . . . πρὸς τὸ συγγενὲς ὁδὸς . . . βαρὺ . . . ποιεῖ, τὸν δὲ τόπον . . . κάτω, 63E4–6), even though it will then be travelling in a direction which someone living on earth has become accustomed (*cf.* εἰθίσμεθα 63A7) to calling *upwards*.

This of course is paradoxical: and I repeat therefore that this *need* not be Plato's meaning. Plato *may* mean to restrict his account to the measurement of earth at the centre, and of fire at the circumference. My point is that if we *do* extend the theory to include the behaviour of fire at the centre and of earth at the circumference then the conclusion is not what Taylor supposes. If fire is measured at the centre, then the implication of Plato's final sentence (63E3–7) will be that the *larger* quantity still moves 'downwards' and is *heavier*.

VI

This conclusion is important for another reason. In an earlier passage of the *Timaeus* Plato makes heavy and light depend upon the number of triangles: a pyramid of fire has fewest triangles and is therefore lightest, the icosahedron of water has more triangles and is heavier (55D–56C). Cherniss takes for granted Taylor's interpretation of the later passage, and therefore finds the two accounts of weight inconsistent, since in the later account a larger quantity of fire he supposes will be *lighter*, when measured at the centre, while in the earlier account the larger quantity of fire has more triangles and is therefore presumably heavier.[11] (The comparison of different portions of the same element, as distinct from the comparison between different elements, is not explicit in the passage I have quoted, but it does seem to be implied, in the continuation of Plato's analysis, 59A8–C3, by the comparison of copper and gold, which are both 'kinds' of water.) On the interpretation that I have proposed, the larger quantity of fire, in the later passage, is invariably the heavier, whether it is measured at the centre or at the circumference: and the two accounts are therefore, in principle at least, consistent.

Nor is the consistency a question of chance. Plato's 'two' theories of weight have been misunderstood because it has not been appreciated that Plato is adopting an essentially Democritean theory of *sensibilia* and of sensations. Hot and cold, sweet and sour, hard and soft, do not exist independently of the sensible percipient. In each case, therefore, Plato describes first the configuration of primary particles that, existing independently of the sensible observer, will give rise to the sensations and effects that we call 'heat' etc. (53C ff.): he then describes the effect of these same particles upon the human or the animal body (61C ff.). Once Plato's plan has been appreciated, the earlier account of heavy and light, far from being a 'passing' and a 'chance' remark, as Solmsen and Cherniss suppose, is seen to be an essential ingredient in Plato's conception of the *sensibilia*. Heavy and light

[11] H. F. Cherniss, *Aristotle's criticism of Plato and the Academy* (Baltimore, 1944) 138–9, 161–5. F. Solmsen writes of the 'illuminating analysis' in Cherniss, *Aristotle's system of the physical world* (New York, 1960) 280 n. 19.

as *pathemata* are the direct result of the number of the primal triangles, which provide as it were the objective correlate in what is otherwise an essentially subjectivist theory of our sensible perception.

If my interpretation of Democritus is correct, the innovation will be that heavy and light are now included, along with hot and cold, sweet and sour, dense and rare, as things that, according to Democritus, exist only 'by convention'.

VII

Aristotle rejects, or perhaps one should rather say adapts, the subjectivist theory of the *sensibilia*. Earlier thinkers, he tells us in the *De anima*, were wrong to suppose that without the faculty of sight white and black would not exist. Without sensation, colours do exist, though only potentially (iii 2, 426a20–6). Aristotle therefore returns to the idea that heavy and light exist, as we might say, 'objectively'. Precisely how they do so, is a complex question which turns partly on Aristotle's distinction between absolute and relative weight, and partly on his use of two criteria for distinguishing both absolute and relative weight, namely displacement and speed. Displacement affords the simpler criterion of the two. Earth falls to a position below every other element, and is therefore heavy absolutely, fire rises to a position above every other element, and is therefore light absolutely, and air and water are both light and heavy relatively to earth and to fire, because they occupy a position midway between the two extreme elements: this is the central theory of the fourth book of the *De caelo*.

The question of speed is more difficult. In Aristotle's main definition, the larger quantity of earth (or fire) moves more quickly downwards (or upwards) than a smaller quantity (iv 4, 311a21). But elsewhere speed is used to distinguish between *different* elements. This happens first in a definition of what is relatively light at the beginning of book four. Aristotle writes that an element will be light or lighter in relation to another if of two bodies that both have heaviness and that are equal in volume or bulk (*ὄγκον*) the other is carried downwards more swiftly (iv 1, 308a31–3).

The definition of relative lightness by means of movement downwards has inevitably caused a good deal of confusion, from commentators as far apart, in time and quality, as Simplicius and Odone Longo.[12] In order to make sense of the definition, we have to suppose that equal quantities of earth, water and air will move downwards each more swiftly in that order. The reason for the inversion is primarily that Aristotle cannot specify the faster element as having either relative or absolute weight, since both earth and water move downwards more quickly than another element: it is only the element which travels downwards *less* swiftly (water or air) which will have relative weight. *Mutatis mutandis*, the situation is roughly the same as in the passage which I first quoted with *τὸ κουφότερον* (iv 2, 309b5–8). The element which is lighter may be either light absolutely (fire is lighter than the other elements) or relatively light (air is lighter than water, water is lighter than earth). It is only the second element in the comparison which, unless it has the opposite form of absolute weight, must be heavy in a relative sense.

The reason why Aristotle spells out only the definition for what is relatively light (it is this which leads Longo to an elaborate emendation) is doxographical. Earlier thinkers, Aristotle tells us in the sentences immediately following, have recognised only elements that have heaviness. (Cap. 2, 308a34–b1. The point of this sentence is not, as Professor Guthrie supposes in his Loeb edition, that earlier thinkers spoke of 'weight and lightness in the relative sense only'; it is that both heavy and light they seek to derive from elements that have only heaviness, i.e. *οὕτω* looks forward to *ὅσων*: . . . *περὶ τῶν οὕτω βαρέων καὶ κούφων εἰρήκασι μόνον, ὅσων ἀμφοτέρων ἐχόντων βάρος θάτερόν ἐστι κουφότερον.*) Thus Aristotle starts from what is recognised, namely what is *heavy*: and the inverted form of his definition leads therefore to an element which is relatively *light*.

[12] O. Longo, *Aristotele 'De caelo', introduzione* etc. (Firenze, 1961).

VIII

At the end of book four, Aristotle refines the notion of speed as a criterion for distinguishing different elements, in the course of a final set of criticisms directed against Plato and the Atomists (iv 5, 312b19–313a13).

If there were a single material principle (ὕλη) for all things, Aristotle argues, whether it were triangles, void, plenum or extended magnitude, then a large quantity of air would contain more of the material principle ⟨than a small quantity of earth does⟩, and it should therefore, Aristotle argues, be carried downwards more quickly. But in fact, Aristotle concludes, 'no quantity of air is ever carried downwards', 312b30–1: *οὐ φαίνεται δ'οὐδὲ ἓν μόριον ἀέρος κάτω φερόμενον.*

What does this final sentence mean? It would be implausible, I think, to emphasise *φαίνεται*: 'air may be carried downwards, but we never see this happening'. And yet the meaning cannot be that 'no quantity of air is ever carried downwards' *tout court:* for earlier Aristotle has specifically stated that air and water are carried downwards in fire (cap. 4, 311a26–7). The answer, I believe, is that the conclusion to the argument follows the sense of the premiss. The premiss to the argument states that in the atomist or the Platonic theory some of the intermediate elements will be carried downwards *more quickly* than earth (312b28–9: *καὶ τῶν μεταξὺ δὴ ἔνια ἔσται κάτω θᾶττον γῆς*). This therefore is the idea that must be repeated in the conclusion to the argument. The meaning will be that 'no quantity of air is ever carried downwards' *more quickly* than any quantity of earth.

This seems to me the only possible sense of Aristotle's argument. Stocks and Guthrie, however, take the final sentence to mean that no quantity of air is ever carried downwards 'in earth'.[13] But this does not answer to the premiss of the argument. Stocks and Guthrie have, I suspect, confused the two terms of the comparison. The comparison lies not between a larger and a smaller quantity of air, carried downwards *in* earth, but between a large quantity of air and small quantity of earth. The criterion of measurement lies then in their speed of fall. On the atomist or the Platonic theory, according to Aristotle, the larger quantity, which is the quantity of air, should fall faster. The obvious implication is that on Aristotle's own theory earth will always fall faster than air.

In his next argument Aristotle deploys the same contrast, but between the intermediate elements, air and water. Again, on the atomist theory, a larger quantity of air will have more solid in it than a small quantity of water has; but this leads to a quantity of air being carried downwards more quickly than a quantity of water, which Aristotle tells us, 'is never seen to happen anywhere, ever' (312b32–313a6). On Aristotle's own theory, therefore, the implication must be that water will always fall faster than air.

IX

This situation needs to be pondered carefully. The difference between Aristotle's final pair of arguments, and the definition of relative weight at the beginning of book four, is that for the comparison between air and water, and for the comparison between air and earth (or, in the upward direction, for the comparison between water and fire), the stipulation of equal volumes or of equal quantities (*ὄγκον*) has been omitted from the calculation of speed. But for the comparison between water and earth (or between air and fire) in the earlier definition the stipulation has not been suppressed. One reason for this, and the less interesting reason, lies, I suspect, simply in the fact: it would be difficult, impossible even, for Aristotle to claim that measured in air no quantity of water could weigh more than any quantity of earth. The more interesting reason for retaining the comparison of equal volumes, or of equal quantities, in the comparison between water and

[13] J. L. Stocks, in the Oxford translation of the works of Aristotle, vol. ii (1930). Guthrie, Loeb edn.

earth (or between air and fire) lies in the motivation of Aristotle's argument, as a refutation of Democritus.

Democritus can have two material principles, on Aristotle's reckoning, void and plenum. By a series of very adroit manoeuvres in the first part of book four of the *De caelo* Aristotle succeeds in avoiding any direct criticism of the use of void and plenum as together an explanation of the differences of weight between different elements. For the truth is that taken as a system with two material principles Democritus' theory offers a serious threat to Aristotle's own distinction between absolute and relative weight, in so far as that distinction rests on the criterion of displacement.

In Aristotle's own theory of composite weight, wood, which has a certain proportion of air and earth, will rise to the surface of water and will fall below air, and will even fall in air more quickly in a larger quantity, while lead, which has a different proportion of earth, will always sink in water (*cf.* iv 4, 311a29–b13). What is there to prevent the objection that in Aristotle's own system fire and earth are the only material principles, corresponding to void and plenum, and that air and water are not elements at all, but bodies compounded of fire and earth in different proportions, which therefore sink below fire and rise above earth, precisely as compound bodies do in Aristotle's own system?

The solution which Aristotle finds lies in extending his criterion of speed. Wood, in a large enough quantity, can fall more quickly than lead, in air, although in a different quantity lead will be heavier, and will fall the faster. But *no* quantity of air, Aristotle decides, can fall more quickly than earth or than water in fire (nor can any quantity of water rise more quickly than air or fire, in earth). Air and water must therefore be independent elements. They cannot be compounded of earth and fire. The relation between water and earth (and between air and fire) Aristotle can afford to ignore, since the difference between these elements is sufficiently established by the criterion of displacement, and is in any case, in practical terms, intractable to differentiation solely by the criterion of speed. But the remaining relationships Aristotle must establish by a criterion other than that of displacement, if he is to succeed in resisting the reduction of his own theory to a version of that material dualism that in Aristotle's mind would be indistinguishable from atomism.

X

This leads to my final, very abbreviated and highly simplified, considerations on the fundamental differences between Democritus' and Aristotle's conceptions of change and identity. For although Aristotle is primarily concerned in his final argument to establish the separate identity of the four cosmic elements, his position in this regard is not a simple one, any more than it was on the question of sensation. In adopting a theory of four elements, Aristotle has not simply reverted to Empedocles' position, although he does see Empedocles as his precursor in this respect. Underlying the four elements there is a further principle of change: *hyle*. As the unity that underlies sensible change we may I think, for historical purposes, compare Aristotle's *prima materia* with the unity that underlies change in Presocratic conceptions, the *apeiron* in Anaximander, fire or *logos* in Heraclitus, and the atoms of Democritus. I take only one comparison, Democritus, and only one theme: the reduction in criteria of identity.

One powerful cause of the modern misunderstanding of Democritus' theory, apparent especially in French writers, under the influence ultimately, I suspect, of Descartes, has been to limit the properties of the atoms to differences that are 'proprement géométriques et analytiquement liées à l'étendue' (Robin's expression).[14] This approach naturally excludes heaviness as a property of the atoms. But this conception is, I think, too sophisticated, even for thinkers of the later fifth century. From both Aristotle and Theophrastus it is clear that the atoms were regularly defined as differing only in their shape, position and

[14] L. Robin, *La pensée grecque* (Paris, 1923) 135–46, see esp. 138.

arrangement. But at least two other criteria which belonged to the atoms were not regularly specified in this list, I suspect because they were taken for granted as inalienable properties of whatever was to be truly 'real'. These are differences of size, and if my earlier reconstruction is correct, differences of weight.

The conception of the substance of the physical world as dependent upon 'geometrical extension', and without weight therefore, is much more nearly Platonic. But Plato's triangles still have shape and size, even if, for the three transformable elements (i.e. excluding earth), the triangles are ultimately all of the same size and all of the same shape (at least they are so on Cornford's interpretation, which I hold to be correct). For Aristotle, the criteria of identity for the unity that underlies change have been still further reduced. The *prima materia* has no fixed shape, it is not particulate and it cannot therefore be distinguished by the position or arrangement of its parts; nor even does it have a definite size, since it may exist in a more contracted or in a less contracted form. In particular, weight, which had clung in an ambiguous form to the Platonic triangles, as the 'objective correlate' of our sensation, has been removed from the primal unity. Along with hot and cold and dry and wet, weight must now attach only to the visible elements that are formed from the primal unity, but with the difference—and hence the complexity of Aristotle's final set of arguments against Democritus—that in the fourth book of the *De caelo* Aristotle attempts to take the single opposition between heavy and light, which in Democritus and in a sense even in Plato had acted as the criterion of a single kind of substance, and attempts to make it apply in a specifically different form to each of the elements.

In the *De generatione et corruptione* the task is simplified by Aristotle's employing two pairs of opposites which can easily be made to generate two 'pairs' of elements (ii 3). But not only is the 'generation' of elements in the *De generatione et corruptione* logically easier, it is also historically less significant. Hot and cold, wet and dry, had already been abandoned, both by Plato and by Democritus, as properties with a properly independent and objective existence. Not so with weight, which if my reconstruction is correct had continued to be thought of as a necessary criterion of material identity, at least for the Atomists. Aristotle's removal of weight is thus a decisive step in abandoning the opposition between appearance and reality as the conceptual cradle of change, so to speak, and in adopting a new opposition between potency and act, where the unity that underlies change is not *most* real, but *least* real, lacking all character save ultimately that of extension, while what was the 'appearance' now becomes the reality, initially a quadripartite reality, and is duly invested with the exclusive possession of the property that had hitherto still clung to its rival: the property of weight.

D. O'BRIEN

Centre National de la Recherche Scientifique, Paris