XVII
The Corpuscularian Hypothesis

(a) *The origins of atomism*

'Leucippus of Abdera, a pupil of Zeno, first excogitated the discovery of the atoms' (pseudo-Galen, **67 A 5**). The attribution seems to be correct: Anaxagoras and Empedocles did not have particulate theories of matter; and Democritus, the great name in ancient atomism, was Leucippus' pupil. Leucippus is naturally praised: we are all atomists now; and we are both obliged and delighted to pay homage to the first inventor of that subtle truth.

A famous paragraph in Newton's *Opticks* states succinctly enough the elements of modern atomism: 'All these things being consider'd, it seems probable to me, that God in the Beginning form'd Matter in solid, massy, hard, impenetrable, movable Particles, of such Sizes and Figures, and in such Proportion to Space, as most conduced to the End for which he form'd them; and that these primitive Particles being Solids, are incomparably harder than any porous Bodies compounded of them; even so very hard, as never to wear or break in pieces; no ordinary Power being able to divide what God himself made one in the first Creation. While the Particles continue entire, they may compose bodies of one and the same Nature and Texture in all Ages; But should they wear away, or break in pieces, the Nature of Things depending on them, would be changed.' Those minute rondures, swimming in space, form the stuff of the world: the solid, coloured table I write on, no less than the thin invisible air I breathe, is constructed out of small and colourless corpuscles; the world at close quarters looks like the night sky—a few dots of stuff, scattered sporadically through an empty vastness. Such is modern corpuscularianism.

Against that Newtonian paragraph let us set Aristotle's description of ancient atomism. The account comes from his lost monograph on Democritus, a fragment of which Simplicius preserves:

> Democritus holds that the nature of what is eternal consists of little substances, unlimited in quantity; and to these he subjoins something else—space, unlimited in magnitude. He calls space by the names 'the void', 'nothing', 'the unlimited'; and he calls each of the substances 'things', 'massy' and 'being'. He thinks that the substances are so small that they escape our perception. There belong to them every kind of shape and every kind of form and differences in magnitude. Now from these, as from elements, he generates and combines the visible and perceptible masses. And they battle and are carried about in the void on account of their dissimilarity and the other differences aforesaid, and in their courses they hit upon one another and bind together with a binding

> that makes them touch and be next to one another but does not generate any genuinely single nature whatever out of them; for it is absolutely silly to think that two or more things could ever become one. The reason why the substances stay together with one another up to a point, he finds in the overlappings and interlockings of the bodies; for some of them are scalene, some hooked, some hollow, some convex—and they have innumerable other differences. Thus he thinks that they hold on to one another and stay together for a time, until some stronger necessity comes upon them from their surrounding, shakes them about, and scatters them apart (**213:** fr. 208=**68 A 37**).

The connexions between Democritus and Newton are evident; and it would be absurd to deny the link between ancient and modern atomism: conceptually, there are narrow ties; historically, an unbroken (if curiously circuitous) line reaches from Leucippus to Rutherford.

Modern atomism is a scientific theory, based upon and confirmed by a mass of experimental data: if the layman does not have those data at his fingertips, the textbooks will refer him to such things as chemical isomerism and Brownian motion. We are tempted, therefore, to welcome Leucippus and Democritus as the founders of modern science.

But there is, alas, no such thing as 'modern science', and the theory I have called 'modern atomism' is a myth: Newton states only one of several very different theories which have been propounded in the last four centuries and which have claimed the name of atomism. There is no unitary atomic theory, invented by Leucippus and successively refined by later scientists; rather, there is a group of theories, loosely connected, all owing something to Leucippus but each differing in vital ways from its companions. Moreover, Newtonian atomism, if I understand aright, is *passé;* and according to the physicist Heisenberg, 'concerning the structure of matter, Plato has come much nearer to the truth than Leucippus or Democritus, in spite of the enormous success of the concept of the atom in modern science'; for 'these smallest units of matter are not physical objects in the ordinary sense; they are forms, ideas which can be expressed unambiguously only in mathematical language'.[1]

Second, by stressing the scientific and empirical aspect of modern atomic theories, we give a false show of virtue to their ancient ancestors: Leucippus and Democritus had not observed Brownian motion; they were largely ignorant of chemistry; they did not rest their atomism on a host of special observations. Their theory was indeed a scientific one, in the old Ionian fashion; it was not a myth, nor an abstract philosophy. But its foundations, unlike the foundations of modern atomisms, were solidly philosophical: if we treat Leucippus as a Presocratic Dalton we shall miss the characteristic touches to his theory.

In short, a naively panegyrical attitude to ancient atomism distorts both the subject and its history. In this chapter I shall gaze at Leucippus and Democritus through antique blinkers: if they restrict the scope of my vision, they may enhance its accuracy.

The first thing to do is to forget the word 'atomism': the Abderite theory[2] was undeniably atomistic; but to label it atomism gives, I think, a misleading prominence to the notion of atomicity or indivisibility. The fragments of Democritus do indeed use the

adjective '*atomos* (uncuttable)', in the neuter phrase '*ta atoma* (sc. *sômata*)', 'the uncuttable [bodies]' **(68 B 9; B 125);** and the doxography uses '*hêatomos* (sc. *ousia*)', 'the uncuttable [being]' (**68 B 141;** cf. **B 167;** Plutarch, **A 57**). But alongside that overtly atomic vocabulary stand other terms: Democritus is said to have referred to the atoms by the word *'phusis'* **(68 B 168)**[3]; Aristotle, an opponent of atomism who devoted much attention to the views of Leucippus and Democritus, regularly uses the words '*to plêres* (the full)' and '*to stereon* (the solid)' to designate the Atomists' material principle (cf. especially *Met* 985b4–22=**67 A 6**); and in his monograph on Democritus, he says that Democritus calls each of the substances [*ousiai*, i.e. the atoms] 'thing *(den)*', and 'massy *(naston)*' and 'being *(on)*' **(213)**.

That last report implies that *den*, *naston* and *on* were Democritus' preferred ways of referring to his substances; and I see no reason to doubt the implication. Indeed, it is tempting to suppose that the term *on* ('being') gives the starting point of Abderite theorizing: the fundamental designation of the Atomists' substances was, trivially enough, *onta*. Abdera, like Elea, embarked upon an inquiry into *onta* and their attributes: the discipline at Abdera was the study of *onta*, of beings *qua* being. Atomism, in its ancient form, begins with metaphysics.

And Abdera follows Elea in thesis as well as in discipline. The first property of Abderite *onta* is solidity: whatever is is *naston, stereon, plêres*. The thesis is starkly Melissan (above, pp. 223–8). The Abderites may indeed have adopted a Melissan style of argumentation for the principle that *onta* are solid; but our sources ascribe neither that argument nor any other to the Atomists, and it may be that they took solidity as a self-evident property of substances: beings, in the primary sense, are plainly bodies;[4] and bodies are plainly solid.

Solid, the Abderites' substances are also eternal, *aïdion* **(213);** they are ungenerable (cf. Plutarch, **68 A 57**) and indestructible (Dionysius, **A 43**). The thesis is Eleatic, and the doxographers duly offer Democritus the old Eleatic argument, 'nothing comes into being from what is not or is destroyed into what is not' (Diogenes Laertius, IX. 44=**68 A 1**); Plutarch indeed ascribes the pseudo-Parmenidean dilemma to him **(68 A 57)**. But that argument is not easily embraced by a man who happily concedes the being of 'what is not';[5] and 'Leucippus thought he had arguments which, by stating what was in agreement with the senses, would not do away with generation or destruction' (Aristotle, *GC* 325a23–5=**67 A 7**). Leucippus wanted to preserve generation and destruction, in some cases at least; he cannot therefore have indulged in the Eleatic argument, and he must have found an argument against the generation and destruction of atoms which would not do away with generation and destruction as such.

Aristotle presents a different argument:

> As for time, with one exception [i.e. Plato] everyone is clearly in agreement; for they say that it is ungenerated. And in this way Democritus proves that it is impossible for everything to have been generated—for time is ungenerated (**214:** *Phys* 251b14–17=**68 A 71**).

Simplicius says that Democritus took the ungenerability of time as self-evident **(68 A 71);** but what did that self-evident axiom prove? Did Democritus merely and trivially urge that since time is ungenerated, then at least one thing, viz. time, is ungenerated? or

did he, more interestingly, urge that some substances at least must be ungenerated, since at any moment in time there must exist some substances, 'empty' time being an absurdity? The interesting argument is, alas, invalid; and in any case, neither the trivial nor the interesting version will show that all substances are ungenerated.

In the absence of a satisfying tradition we are tempted to invent; and an argument for substantial eternity can be cooked up: I shall postpone the concoction for a few pages.

Solid and eternal, Abderite substances are also immutable:

> The atoms do not suffer *(paschein)* or change, by reason of their solidity (**215:** Plutarch, **68 A 57**);

they are 'impassive *(apathês)* because of their being massy and having no share in the void' (**217:** Simplicius, **67 A 14**).[6] 'Impassivity' is unalterability: a body is *apathês* if any features it ever has it always has. Impassivity, again, is an Eleatic property; but the Abderites did not use an Eleatic argument to establish it. Instead they argued that solidity rules out mutability. Why should that be so? Why may a solid body not change its colour or its temperature? Why cannot an atom grow wet or become smooth? The questions require a detour.

(b) *Atoms characterized*

I turn now to the property *par excellence*, the eponymous property, of Abderite substances: atomicity. Atoms are indivisible, uncuttable, unsplittable; they are the ultimate and unanalysable bits out of which the material world is constructed. That Abderite property is no more an Abderite invention than solidity, ungenerability or immutability: Eleatic entities, whether Parmenidean or Melissan, do not divide. It is not easy to disentangle what the Eleatics said about division; but it is clear enough that the first atoms came from Elea.[7]

If the atomic thesis is Eleatic, the arguments by which Leucippus and Democritus supported it were fresh. I begin with a perforated quotation from Simplicius; the holes will be made good later:

> Those who rejected unlimited cutting, on the grounds that we cannot cut without limit and thus gain evidence for the incompletability of the cutting, said that bodies consist of indivisibles and are divided into indivisibles—except that Leucippus and Democritus think that not only their impassivity, but also their smallness…explains why the primary bodies are not divided, whereas Epicurus…says that they are atoms because of their impassivity **(216:67 A 13)**.

In another passage Simplicius says of Leucippus, Democritus and Epicurus that

> they thought that [the principles] are atomic and indivisible and impassive because of their being massy and having no share in the void;

> for they said that division comes about by virtue of the void in bodies **(217:67 A 14)**.

In the same mood, Dionysius says of Epicurus and Democritus that 'both say they are atoms, and are called so, because of their indissoluble solidity' **(68 A 43)**.

These passages appear to contain four distinct arguments: (A) We cannot cut bodies infinitely often **(216);** (B) the primary bodies are impassive **(216);** (C) the primary bodies are solid **(217; 68 A 43);** (D) the primary bodies are small **(216)**. All four arguments are explicitly ascribed both to Leucippus and to Democritus;[8] and there is no reason why they should not have advanced more than one argument in favour of indivisibility.

I begin with argument (D), which according to Simplicius was not adopted by Epicurus. Epicurean atoms were all very small—indeed imperceptibly so (*ad Hdt* §§55–6), and the same is regularly said of Democritus' substances: according to Aristotle, 'he thinks that the substances are so small that they escape our perception' **(213);** But there are three curious passages to the contrary: according to Diogenes,

> the atoms are unlimited in magnitude and quantity (**218:** IX. 44=**68 A 1**):

and the most plausible gloss of that text gives Democritus atoms of every size. Again, Dionysius contrasts Epicurus with Democritus on precisely this issue:

> They differ to the extent that the one [sc. Epicurus] thought that they are all very small and for that reason imperceptible, while Democritus held that some atoms were actually very large **(219:68 A 43)**.

Finally, Aëtius avers that in Democritus' view

> it is possible for there to be an atom the size of the universe **(220:68 A 47)**.

Epicurus attacks the view that 'every size exists among the atoms'; for were it true, then 'some atoms would be bound to reach us and be visible—but that is not seen to happen, nor can we conceive how an atom might become visible' (*adHdt* §§5 5–6). It is natural to suppose that Epicurus is attacking a real target; and Democritus is the obvious candidate.[9] On that assumption Epicurus' text yields a nicer message: if Democritus both allowed that some atoms could be visible and also denied that we ever perceive any, that would account for Epicurus' two objections: that visible atoms are simply inconceivable, and that if there could be such things they would be sure to have come to our notice.

Suppose, then, that Democritus said something like this: 'The primary bodies are not essentially small: as far as logic goes, there may be atoms of a cosmic size. As far as science goes, there must be a variety of atomic sizes. As far as experience goes, it seems that all the primary bodies in our part of the universe are too small to be perceived.' That view is self-consistent; and it accommodates, more or less, all the superficially irreconcilable evidence we possess. It carries an important consequence: smallness is at

best a contingent property of the primary bodies; it is not a feature of *onto, qua onta* that they are imperceptible. Simple observation suggests that all macroscopic objects, even the most durable, can be smashed, split, broken, crushed or whittled away in the course of all-devouring time. Since the primary bodies are unsplittable, and macroscopic things split and dissolve, the primary bodies are microscopic. The argument is healthy; and it is *a posteriori*.

What of argument (D)? Democritus may have said something like this: 'The primary bodies are in fact very small; so small, indeed, that they defeat the finest blade of the sharpest knife; and hence they are indivisible.' The argument is naive: we are not impressed by the hypothetical suggestion that if Democritus cannot get his pocket-knife into an atom, atoms cannot be split. And if, as I imagined, Democritus argued that atoms must be small because they are unsplittable, he can hardly also urge their atomicity on the grounds of their minuscule size.

Argument (B) is curious. It occurs only in **216,** where Simplicius ascribes it to Epicurus, as well as to the Abderites. Now Epicurus' surviving argument for indivisibility goes thus: 'These are atomic and changeless…being full in their nature, not having any way or means by which they will be dissolved' (*ad Hdt* §§4l). The passage presents argument (C); and it explains the reports of Dionysius in **68 A 43** and of Simplicius in **217**. It puts impassivity on a par with indivisibility; and that seems to be its proper place: how then, can impassivity ground indivisibility? Argument (B) is found only in **216** and it is intrinsically implausible: I wonder if Simplicius is not using *'apatheia'* loosely here; perhaps it denotes solidity and 'argument (B)' is merely a ghost of argument (C). At all events, if that suggestion is rejected, then in **216** Simplicius ascribes to Epicurus as his sole argument for indivisibility a train of reasoning found nowhere else; and he ignores a genuinely Epicurean argument which elsewhere he shows himself perfectly familiar with.

Argument (C) rests on the firm Abderite thesis of solidity: atoms are indivisible because they are solid, i.e. because they contain no void; and solidity precludes division because division must occur 'in virtue of the void'. I take it that we have here a physical, not a metaphysical, hypothesis: in order to split an object we must be able to get a knife between its parts and prise them away from one another; but in a solid body there is no vacant gap, however narrow, into which the knife-blade might be inserted. We can only cut along the dotted line; and solid bodies offer no vacancies or dots. Solidity does not logically imply indivisibility; but the physical process of division requires a porous body to work upon.

An objection arises: take two atoms and juxtapose them so that there is no void in the interstices between them; then by the argument I have just offered they cannot be parted; yet on atomist principles any two atoms may be conjoined and parted. I guess that Leucippus anticipated that reflexion: Aristotle says that Leucippan atoms may 'touch', *haptesthai* (*GC* 325a33=**67 A 7**); Philoponus offers the following gloss:

> Democritus does not use the word 'touch' strictly when he says that atoms touch one another;…but he talked of touch when the atoms are near one another and not far away—for they are in any event separated by void (**221:67 A 7**—the same view is ascribed to Leucippus, ibid.)

Between any two atoms there is always a void; hence they can never conjointly form a solid molecule, and they can always be separated (cf. Alexander, **68 A 64**).

In the same passage of the *GC* Aristotle reports that:

> From what is truly one, a plurality *(plêthos)* could never come about, nor one from what are truly plural; but that is impossible (**222:** 325a35–6=**67 A 7;** cf. **213;** *Cael* 303a6).

The second part of the doctrine will prove important later; here my concern is with its first part: 'no plurality from a unity'.

It is possible that Aristotle is merely elaborating upon argument (C): units are solid; hence they cannot be split; hence they cannot yield a plurality. But the *Metaphysics* suggests a more sophisticated view:

> If a substance is a unit, it cannot consist of inherent substances in this way, as[10] Democritus rightly says; for he says that it is impossible for one thing to come from two or two from one (for he makes the atomic magnitudes his substances) (**223:** 1039a7–11= **68 A 42**).

The argument is this: 'Democritus' bodies are substances; substances are units, i.e. not aggregates; hence no substance can split into two or more substances; hence no Democritean body can split'. That genuine substances cannot be aggregates is a Democritean view, and it has had many adherents (see below, p. 445). Yet if a substance cannot *be* an aggregate, may it not *become* one? why cannot a unit split up and become a plurality? Aristotle's text suggests that if *b* and *c* 'come from' *a* at *t*, then prior to *t* they must have conjointly constituted *a,* so that *a* consisted of 'inherent substances' and was an aggregate. Why should that be so? Well, neither *b* nor *c* can be identical with *a;* since each is, by hypothesis, a part of *a*. But in that case either *a* ceases to exist at *t* (which is impossible, since substances are eternal), or else *a* was all along the aggregate of *b* and *c* (and hence not a primary substance). In short, substances are unitary and eternal; hence they cannot split.

That account provides a philosophical argument for indivisibility; and one of some power. If I hesitate to put it alongside (A)—(D) and ascribe it to Democritus himself, that is because no source outside the *Metaphysics* knows it. Probably, it is a genial Aristotelian development of Democritean views; but it is, at worst, a development fully in the spirit of atomism.

I have left argument (A) to last; it too appears only once in our sources, and perhaps it is an invention by Simplicius. It is, however, worth a brief exposition. If I read it aright, it goes thus: 'We cannot actually divide any body into infinitely many parts; hence we can never have reason to believe that bodies are infinitely divisible; hence we should believe that bodies are not infinitely divisible.' We cannot have evidence for the falsity of atomism: we therefore have reason to believe it true.

The principle behind the argument is this: if we cannot have evidence that not-*P*, we should believe that *P*. In a weaker form (if we do not have evidence that not-*P*, we should believe that *P*) the principle has supported any number of bad arguments. Why the principle is popular I do not care to guess; that it is false is evident: if I have no

evidence for not-*P*, I may also have no evidence for *P;* and in most cases it is irrational to believe that *P* without having evidence for *P*. Moreover, the application of the bad principle to atomism requires the use of a second bad principle. For in asserting that because we can never actually cut up a body infinitely often, we can have no evidence for infinite divisibility, the Atomists appear to assume that we have no evidence that *P* is true unless we possess knowledge that entails *P*. And that is absurd.

Thus argument (A) is both ill-attested and disreputable. Yet it has two points of mild interest. First, it is the earliest example of a perennially seductive mode of argumentation. Second, it introduces a different problem from those dealt with by arguments (C)—(D): they argue that substances are indivisible; it argues that there are indivisible substances. It is one thing to show that no substance can be divided, another to prove that there exist indivisible substances. The former task is futile unless the latter has been successfully undertaken (what scientist cares for a proof that unicorns have only one horn?); and, if we disregard argument (A), the Atomists have not yet attempted the latter task. The question will arise again.

It is fair to say, I think, that solidity supplies the chief argument for the eponymous atomicity of Abderite substances. Atomicity is not inferred *a priori* from solidity: the inference rests upon a physical thesis about the nature of splitting. Impassivity or immutability also depend on solidity. I suggest that here again we must supply a physical hypothesis as the link in the logical chain: alteration was deemed by the atomists to involve either the splitting or the combining of atoms; a cubic atom, say, could only become spherical if bits were chipped off or added to it (or both); an atom could only grow or diminish by the addition or the loss of bits of stuff. (And those, as we shall see, are the only intrinsic changes an atom could possibly undergo.) But a solid atom cannot have bits chipped from it; and an atom with bits conjoined to it will never constitute a solid body. That may, I suppose, be Aristotle's meaning when he says:

> It is necessary to say that each of the indivisibles is impassive, for it cannot 'suffer' except through the void (**224:** *GC* 326a1–3).

It is tempting to find a similar connexion between solidity and ungenerability (cf. Plutarch, **68 A 57**). The generation of macroscopic objects, according to the Atomists, consists merely in the rearrangement of particles at the microscopic level. Did they reject microscopic or atomic generation on the basis of a similar thesis? An atom *a* could only be generated in virtue of some rearrangement of sub-atomic particles; but such a mode of generation is impossible: were *a* compounded from sub-atomic fragments, it would not be solid; and were there sub-atomic parts, they could only have been produced by the shattering of an atom. Since atoms are solid, they cannot have been put together; and such a putting together is the only sort of generation not evidently outlawed by Eleatic logic.

My discussion has rambled; and it may be convenient to provide a summary before advancing any further. The Atomists asked themselves what were the properties of *onta qua onta;* and (as I have surreptitiously presupposed) they were concerned with *onta* of the primary sort, with *ousiai* or substances.

Every substance, they argued, was *unitary* (not an aggregate) and *solid*. What is solid is, by a physical necessity, *indivisible* or atomic; and what is unitary is indivisible by

logical necessity. What is solid is, again by physical necessity, *eternal* (or ungenerable and indestructible); and also *immutable* or impassive. Primary substances are bodies, solid and unitary; they are physically indivisible, they endure for ever; and they are subject to no change. That, I think, constitutes the basic account of the Abderite theory. We may now proceed to its further elaboration.

(c) *Fractured atoms?*

Atoms, though indivisible, may have parts: we may not be able, physically, to split an atom; but we can, theoretically, divide it into notional parts: 'the half nearer to *b*', 'the part with the point on', and so on. And if we take a large Democritean atom we may even be able to measure it, to mark it into parts, to draw a design upon it; the only thing we cannot do is cut it along our marks or carve it to the drawn design. The doxographers say nothing about the notional parts of Abderite atoms; but both Alexander (*in Met* 36. 25–7) and Simplicius (*in Phys* 82. 1–3) mention them casually.

Epicurus said more about sub-atomic particles (*ad Hdt* §§58–9). His views are controversial;[11] but an orthodox interpretation runs thus: every atom is theoretically, but not of course physically, divisible; but just as physical splitting eventually reaches atoms or physical indivisibles, so too theoretical division ultimately reaches *minima* or theoretical indivisibles; and an atom is thus composed of a finite set of theoretically indivisible *minima*, conjoined by a physically indissoluble bond. Epicurus is a second-hand thinker; and it is proper to wonder if his theory was not taken from Democritus, along with the other trappings of atomism. Alexander implies that it was:

> [Leucippus and Democritus] do not say whence the weight in the atoms comes; for the partless items *(ta amerê)* conceptually present in *(epinooumena)* the atoms and parts of them are, they say, weightless: but how could weight come about from weightless components? (**225:** *in Met* 36.25–7).

I shall return to the issue of weight in a later section. Here I am concerned only with Alexander's assertion that the Abderite atoms have conceptually distinguishable parts which are themselves conceptually partless. That is precisely Epicurus' view.

Few scholars believe Alexander, imagining that he is, carelessly or deliberately, projecting back onto the Abderites a theory he found in Epicurus. And it is observed that Aristotle nowhere distinguishes between atomic and sub-atomic indivisibles in his many discussions of Abdera, even though in one or two passages (e.g., *Cael* 303a21) he could hardly have failed to mention the distinction had he known it. Arguments *e silentio Aristotelis* are not conclusive; and Democritus may, I suppose, have advanced the Epicurean theory in an inconspicuous or informal fashion; but I doubt it, and I shall proceed on the assumption that Alexander's report is in error.[12]

A somewhat subtler suggestion now presents itself. Suppose that Democritus had held his substances to be both physically and theoretically indivisible; then Epicurus is still a follower, but not a slavish adherent: he retains both varieties of indivisibility in his theory, but attaches them to different objects. Where Democritus asserted that atoms

were both physically and theoretically indivisible, Epicurus maintained that atoms were physically indivisible, their minimal parts theoretically indivisible. Democritus does not allow sub-atomic particles, notionally distinguishable within the atom: his atoms have no parts at all—neither by the axe nor by the mind can you splinter them.

Are Democritean atoms theoretically indivisible? Some scholars think that they are, arguing thus: The Abderites were concerned, *inter alia*, to answer Zeno's dichotomy arguments; only theoretically indivisible atoms will give them an answer. Hence they ought to have embraced theoretical indivisibility. Moreover, several ancient texts in fact support the attribution of theoretical indivisibility to the Abderite atoms.' I shall first set this argument out in more detail, exhibiting the texts on which it is based, and then offer some critical comments.

At *Physics* 187a1 Aristotle reports thus:

> Some surrendered to both arguments—to the one concluding that everything is one (if being signifies one thing) by saying that what is not is; to the one from the dichotomy, by positing indivisible magnitudes **(226)**.

Plainly 'some' refers to the Atomists;[13] for only the Atomists *both* said that 'what is not is' *and* posited 'indivisible magnitudes'. It is the second move that we are concerned with here: Aristotle represents atomism as an answer to Zeno's dichotomy argument.

The brief notice in the *Physics* is expanded in the *de Generatione:*

> One can see from this too the great difference between those who study scientifically *(phusikôs)* and those who study dialectically *(logikôs)*. For on the question of atomic magnitudes, some [i.e. the Platonists] say that the triangle itself will be many [sc. if there are no atomic magnitudes], but Democritus would seem to have been persuaded by appropriate and scientific arguments. What we mean will become clear as we proceed (**227:** *GC* 316a10-14).

There follows an involved argument, of Zenonian flavour, which I have already mentioned (above, p. 247). I summarize it as follows: 'Suppose a magnitude is infinitely divisible, and that such a division is possible. Carry it out: what are you left with? Not a magnitude; for then you have not carried out the division. Not nothing; for bodies are not compounded of nothing. Not points; for points cannot constitute a magnitude. It won't do to suppose that the process of dividing produced some quantity of sawdust; for the same questions apply to that. Nor can you say that the division separates qualities from underlying points or contacts' (*GC* 316a15-b19=**68 A 48b**). Aristotle then offers to 'restate' the puzzles (316b20–8), and concludes with the following paragraph:

> But that it divides into magnitudes that are separable and always smaller and apart and separated, is evident. Now if you divide part by part the breaking will not be unlimited, nor can it be divided at every point at the same time (for that is not possible), but only to a certain point. Necessarily, then, invisible atomic magnitudes inhere in it, particularly if

> generation and destruction is to come about by dissociation and association. This, then, is the argument that seems to necessitate the existence of atomic magnitudes (**228:** *GC* 316b28–317a2).

The *GC* expands the brief aside of the *Physics:* Zenonian anxiety causes the spots of atomism.

Four passages, or groups of passages, support the inference drawn from the *GC*. First, in a passage I mangled earlier, Simplicius says:

> …except that Leucippus and Democritus think that not only their impassivity but also their smallness and their partlessness explains why the primary bodies are not divided, whereas Epicurus later does not regard them as partless but says that they are atoms because of their impassivity (**229:67 A 13**—cf. **216**).

By 'partlessness *(to ameres)*' Simplicius clearly intends theoretical indivisibility;[14] otherwise the contrast with Epicurus is nonsensical.

Second, a scholiast on Euclid X.1 reports:

> That there is no smallest magnitude, as the Democriteans say, is proved by this theorem, that it is possible to take a magnitude less than any given magnitude **(230:68 A 48a)**.

The report is iterated by Simplicius (*in Cael* 202.27–31).

Third, the passage in the *de Caelo* on which Simplicius thus comments illustrates the catastrophic results of a small initial error:

> E.g. if someone were to say that there is a smallest magnitude; for he, by introducing a smallest, overthrows the greatest part of mathematics (**231:**271a9–11).

The same accusation is levelled later against Leucippus and Democritus:

> Again, it is necessary that those who talk of atomic bodies clash with the mathematical sciences, and do away with many reputable opinions and data of perception, about which we have spoken in our remarks on time and motion (**232:**303a20–4).[15]

Atomism clashes with mathematics only if atoms are theoretically or mathematically indivisible.

Finally, there is a strange passage in Plutarch usually supposed to quote Democritus' own words:

> If a cone is cut by its base in a plane, what should one think of the surfaces of the segments—are they equal or unequal? For if they are

> unequal, they will make the cone uneven, with a lot of step-like corrugations and roughnesses; and if they are equal, the segments will be equal and the cone will evidently have suffered the fate of a cylinder, being constructed from equal and not unequal circles—which is utterly absurd **(233: B 155)**.

The fragment connects with a further passage in the *de Caelo* (307a17 =**B 155a**) which appears to ascribe to Democritus the view that a sphere has angles, i.e. is a polyhedron. Why should a cone be corrugated and a sphere polyhedral? The only explanation is that geometrical solids are composed of theoretically indivisible parts.

So much for the texts on which theoretical indivisibility is founded. Before examining them it will be prudent to ask just what thesis they are supposed to maintain: what does it mean to say that atoms are 'theoretically' indivisible?

First, the thesis might be that atoms are *conceptually* indivisible: we cannot conceive or think of anything smaller than an atom. Conception is treated as a form of imagining; and the thesis amounts to saying that there is a lower limit to our powers of imagination: just as there is a threshold to our physical eye, so there is a threshold to our inner eye. Some things are too small to be seen; others would be too small to be imagined or conceived. That, if I understand him, is Epicurus' notion of theoretical indivisibility (*ad Hdt* §§58–9); and it was revived by Hume. It is a wretched muddle; for it confounds thinking or conceiving with the forming of mental images; and it supposes that to imagine a small object is to form a small image. But I shall not attempt to tease out all the horrible confusions it contains.

Second, the thesis might mean that atoms are *geometrically* indivisible: the volume occupied by an atom has no mathematically distinguishable parts; there is no quantity designated by such phrases as 'half the volume of an atom', 'two thirds the volume of an atom', and so on. 'But surely,' it is said, 'Democritean atoms are magnitudes, *megethê*, and not points (like the atoms of Boscovich); but all magnitudes (in Euclidean geometry at least) are divisible: hence those atoms are not geometrically indivisible—Democritus was "too good a mathematician" to maintain any such view.'[16] But we know that Plato and Xenocrates both entertained a theory of geometrically indivisible magnitudes (above, p. 245), and we may not deny on *a priori* grounds that Democritus anticipated them. There is no *geometrical* error in abandoning the continuous space of Euclidean thought and substituting a granular space; and the theory that atoms are geometrically indivisible is the theory that the geometry of space is granular, that space is made up of minimal volumes.

Finally, the thesis of theoretical indivisibility might mean that atoms are *logically* indivisible: the notion of a sub-atomic body is self-contradictory. There is a trivial sense in which atoms are logically indivisible; for 'atomic' *means* 'indivisible', so that '*a* is an atom and *a* is divisible' is a simple contradiction. But that trivial thesis is not what the supporters of 'theoretical' indivisibility have in mind; for it states only that, as a matter of logic, physically atomic bodies are physically indivisible. Rather, supporters of 'theoretical' indivisibility maintain, on this interpretation, that if *a* is an atom, then it is logically impossible to divide *a*. And that thesis is not a trivial truth: it asserts that atomicity is an essential trait of atoms, much as being even (say) is an essential trait of the number 2.

Theoretical indivisibility is not a unitary thing: which sort of indivisibility, if any, is suggested by the texts I have referred to?

233 is, I think, entirely inconclusive. It presents a dilemma, and the dilemma is based on the supposition of an atomist geometry. 'Take a cone of *n* atomic lengths from base to apex, and divide it into *n* segments. Consider the top surface of segment *i*, and the bottom surface of segment *i*+1: if the former is greater than the latter, the cone will be corrugated or stepped, like a ziggurat; if the two surfaces are of the same area, the solid will be cylindrical.' Such a reconstruction makes sense of **233** and provides a genuine dilemma. And we may safely infer that Democritus had envisaged the possibility of a non-continuous geometry. Some scholars think that Democritus accepted the first horn of the dilemma: cones are indeed ziggurats; and they infer that Democritus embraced geometrical *minima*. Others think that the dilemma was intended rather as a *reductio adabsurdum* of the notion of such *minima*. We cannot tell: each interpretation is plausible, neither can be favoured.[17]

B 155a is more to the point: if a sphere has angles, then surely that can only be because its surface is composed of minimal planes. But apparently Democritus said not that a sphere 'has angles' but that it 'is an angle *(gônia)*'; and Simplicius offers the following explanation:

> The spherical whole is an angle *(gônia);* for if what is bent *(sunkekammenon)* is an angle, and a sphere is bent at every point on its surface *(kath' holên heautên),* then it is reasonably called a whole angle *(holê gônia)* **(234: B 155a)**.

Geometers who talk of 'straight angles'—angles of 180°—do not suppose that straight lines are really bent: Democritus' phrase 'whole angle' need not imply that spheres are really polyhedrons.[18]

Next I turn to *de Caelo* 303a21 and the clash between atomism and mathematics. Surely, the physical indivisibility of atoms cannot pose any problems for mathematics; if there is a clash, it can only be caused by a mathematical indivisibility? The answer is not as simple as it seems; for the question at issue is not whether physical indivisibility conflicts with mathematics, but rather whether Aristotle would have deemed such a conflict to exist. And I think that he would have done: in the *Physics* he argues that since the universe is finite in extent, there are no infinite magnitudes for the geometers to reason about (207b15–21); and he excuses himself by saying that the geometers can get by if they are allowed to divide an object at any point (207b27–34). Geometry, for Aristotle, is essentially an applied science: it talks about lines and planes in the physical world, idealizing them, but for all that treating of them and not of objects of a more aetherial nature. Geometers assume that their subject matter is continuous or divisible at any point; but their subject matter, in Aristotle's view, is the physical world; consequently, the geometers will be at odds with any theory of *physical* indivisibles. If that is so, the *de Caelo* does not provide evidence that Democritean atoms are theoretically indivisible; Aristotle's criticism of atomism, given his own views on the nature of geometry, is compatible with the assumption that he ascribed only physical indivisibility to the Atomists.[19]

Simplicius, *in Cael* 202.27–31, and the scholiast on Euclid depend on the *de Caelo;* and their statements give no independent evidence for mathematical atomism. In **229,** on the other hand, Simplicius is not simply drawing on Aristotle; and there he must be using 'partless *(amerês)*' in the sense of 'theoretically indivisible'. Now Simplicius' ascription of 'partlessness' to the atoms is singular; and I am inclined to think that it is an inference of Simplicius' own.[20] *'Amerês'*, I suggest, is Simplicius' gloss on '*smikros* (small)': wanting to explain the inference from smallness to indivisibility; believing (on the basis of the *de Caelo*) that the Atomists' corpuscles were geometrical *minima;* and observing that, unlike Epicurus, the two founders of atomism did not say anything about the 'parts' of their atoms, he understandably inferred that *'smikros'* in their argument connoted theoretical indivisibility. We need not accept Simplicius' inference; and **229** drops from the controversy.

All depends, then, on the Aristotelian view that Atomism grew from a reflexion upon, or a surrender to, Zeno's dichotomy argument. How much of the long argument, or set of arguments, in the *GC* we can safely ascribe to Democritus I do not know: Aristotle speaks tentatively—'Democritus would appear to have been persuaded'—and the passage which I summarized is certainly Aristotle's in form even if it is not so in substance.[21] In any case, I do not see that the argument says anything about 'theoretical' divisibility: Aristotle praises Democritus for arguing *phusikôs,* and that should mean something like 'with a close eye on the relevant scientific facts'—facts, presumably, about physical division. The argument is expressly designed to refute the hypothesis that 'a body is divisible throughout, and that is possible' (316a16): I take that to mean 'bodies are physically divisible through and through, and you can actually effect the division'; for the curious *addendum* 'and that is possible' is otiose unless we read it as meaning 'and you can actually effect the division'. Moreover, the argument speaks of actually dividing a 'body or magnitude', and it refers, only half-jestingly, to the possibility that the process of division may generate a sort of sawdust. All that, and the very language of the argument, suggest a physical and not a notional division. In sum, as I read the passage from the *GC,* it has Democritus reply to the Zenonian argument by positing physically indivisible atoms.

We are left with *Physics* 187a1. Can a physical atomism be represented as a surrender to Zeno's dichotomy? Plainly, if we develop the argument of **29 B 1–2,** we can produce a position which cannot be answered or evaded by positing a physical atomism; certainly, no one who is gripped by the hideous claws of Zeno's logic will think highly of a scientist who simply shrugs his shoulders and says, 'Well, then, I suppose matter is composed of physically indivisible atoms'. But for all that, we can, I think, make sense of Democritus' 'surrender to the dichotomy' without introducing notionally indivisible particles—and that in either of two ways. First we might suppose that Democritus read Zeno's Dichotomy and took it at its face value, as an argument about physical division; had he done so, he would have been justified, if intellectually unadventurous, in asserting physical atomism and getting on with his scientific work. For as Zeno states it, the paradox is adequately solved by physical atomism (see above, p. 245). It is only when we reflect upon that solution, and attempt to reconstruct the paradox in its face, that we develop an argument impervious to physical atomism. And there is no reason to ascribe such reflexion to Democritus. Second, and more easily, we may construe *Physics* 187a1 in the light of the argument in the *GC:* when Aristotle says

that Democritus gave in to 'the argument from the dichotomy' he need not have any precise Zenonian argument in mind; the term 'dichotomy' was certainly used later to refer to any argument of that Zenonian type—any argument turning on considerations of infinite divisibility—and it seems to me most probable that the argument to which, in Aristotle's opinion, Democritus 'surrendered' was none other than the quasi-Zenonian concoction in the *GC*. Thus if the *GC* does not drive us to mathematical atomism neither does the *Physics*.

I conclude that the evidence does not oblige us to make the Atomists' corpuscles theoretically indivisible; the verdict must be *non liquet*. But the investigation of theoretical indivisibility is not wholly negative in its results: I do not want to claim that Aristotle's account in the *GC* has no historical value; on the contrary, I suppose that it gives us the answer to the outstanding question of atomism: Why imagine that there are any physical *minima* in the material world? Leucippus and Democritus, reflecting in a vaguely Zenonian fashion on physical division, urged that unless macroscopic bodies were ultimately composed of indivisible corpuscles, the material world would fall apart into insubstantial points or bare nothings. When asked to explain what feature of these hypothetical corpuscles could account for their indivisibility and prevent their dissolution, they produced a plausible physical answer: substances are solid, and what is solid cannot be divided. The dichotomy argument assures us that there *are* indivisible corpuscles; further considerations, which I have already rehearsed, explain *why* those corpuscles are indivisible.

Unfortunately, the Atomists mishandle the dichotomy argument. I shall not expose their errors; for my remarks on Zeno have implicitly indicated them. But it is worth noting one fallacy in their reasoning: consideration of what would happen if everything were actually divided through and through leads them to infer that:

(1) It cannot be the case that everything has been divided.

From (1) they conclude to atomism, or:

(2) There are some things which cannot be divided.

From a proposition of the form '$\sim \Diamond (\forall x)\phi x$' they infer the corresponding proposition of the form '$(\exists x) \sim \Diamond \phi x$'. The invalidity of the inference, which is hidden in the dowdy garb of ordinary language, shows up clearly when it is more formally dressed. Zenonian considerations will only lead to atomism by way of a fallacy.

(d) *Bodies without number*

There are infinitely many atoms. Simplicius has an interesting report:

> Thus they reasonably promised that, if their principles were unlimited, they would account for all affections and substances and explain under what agency and how anything comes into being; and for that reason they say that only for those who make the elements unlimited does everything turn out in accordance with reason **(235:68 A 38)**.

Observe the character of that argument: only if the atoms are infinite can the phenomena be explained; only an infinity of principles can account for the variety and

vacillations we observe among macroscopic substances and their affections. The attitude evinced in such an argument is resolutely un-Eleatic; to Melissus, the phenomena required no explanation: reason, by dictating a rigid monism, revealed the plural world of sense-perception as a false imagining of the jaded mind. In the north of Greece they had a robuster sense of reality: the things we see and touch cannot be mere fictions; monism must be mistaken, and the plural phenomena require an explanation.

Yet Simplicius' argument will not do as it stands: perhaps an infinity of atoms is sufficient to explain the diversity of phenomena. But is it necessary? Or can any other arguments lead us to postulate an infinity? In fact three further lines of thought have been discerned. First, the Atomists believed that there was an infinite variety of atomic shapes; and that belief immediately entails an infinity of atoms. I shall return shortly to the question of atomic shapes: here I note only that the easy inference from shape to quantity is nowhere ascribed to the Atomists in our sources.

Second, Simplicius says that

> [Leucippus] hypothesized unlimitedly many eternally moving elements—the atoms—and the unlimited quantity of the shapes among them because nothing is rather such than such, and as he observed unremitting generation and change in existent things **(236:67 A 8)**.

Did the observation of 'unremitting generation and change' ground the numerical infinity of the atoms? and does Simplicius ascribe to Leucippus the argument elsewhere ascribed to Anaximander (see above, p. 30) that eternal generation requires an infinite fund of matter or material particles? I do not think so: as I read Simplicius' text, the observation of 'unremitting generation and change' was adduced to establish the eternal motion of the atoms rather than their numerical infinity.

The third argument infers the infinity of the atoms from the infinity of the space in which they swim. Before examining it, therefore, we might well ask why space should be deemed infinite. Our texts contain no direct answer to that question; but a celebrated argument has been adduced to fill the evidential gap.

> Archytas, according to Eudemus, put the argument thus: 'Standing at the edge (e.g. at the heaven of the fixed stars), could I extend my hand or my cane outside it or not?' That I could not extend it is absurd; but if I do extend it, then what is outside will be either body or space (**163:** Eudemus, fr. 65 W=**47 A 24**).

Lucretius took over Archytas' argument (I. 968–983); hence Epicurus used it: and if Epicurus, why not Democritus?[22]

The Archytan dilemma presupposes that every finite extension has edges; for Archytas imagines himself at the edge of the universe. That presupposition links the dilemma to an argument which Aristotle cities as the fourth of five alleged proofs of the existence of the infinite:

> Again, what is finite is always bounded by something; so that necessarily there is no boundary, if it is always necessary for one thing to be bounded against another (**237:** *Phys* 203b20–2).

That argument too was accepted by Epicurus (*ad Hdt* §41); and it too may have originated with Democritus.[23]

Aristotle answers the argument by distinguishing between 'being bounded *(peperanthai)*' and 'touching *(haptesthai)*': what touches, he asserts, must indeed touch something else; but what is bounded need not be bounded by anything else (*Phys* 208a11-l4). The answer is perplexing, and Epicurus was rightly unimpressed by it; yet for all that, Aristotle was unwittingly correct. We are all familiar with two-dimensional extensions that are finite and yet have no edges—'finite and unbounded', in the jargon of the geometers. The surface of a football is a mundane example of such an apparently paradoxical thing. Why, then, should there not be three-dimensional extensions that are finite and unbounded? finite, in that they contain no straight lines of infinite length; unbounded, in that they have no edges. If I understand the doctrine that space-time is 'curved', it implies that our familiar space has precisely those properties.

The Epicurean argument fails; and with it goes Archytas' dilemma; for the presupposition of that dilemma proves unsatisfactory: it is not true that every finite extension has edges. Yet would the dilemma work if its presupposition were true? I do not think so; for I do not see why it is 'absurd' to suppose that I simply could not extend my hand were I in Archytas' situation. Lucretius suggests that if I cannot extend my hand, then there must be something in the way, preventing the extension; but there may be something behind me (a gravitational field, say), holding me back. 'But even if you cannot, physically, extend your hand, still it is logically possible to do so.' Perhaps; but to say that it is logically possible for me to extend my hand two feet in front of me is not to say that there is a *place* two feet in front of me. And Archytas' argument is designed to show that there must be a space (occupied or unoccupied) in front of me.

So much for infinite space. How is it connected with the infinity of the atoms? Plainly, if there are infinitely many atoms, each of a minimum size, space must be infinite if it is to contain them; but if space is infinite, why must it have infinite denizens? Epicurus argued that 'if the void were infinite and the bodies finite, the bodies would not stay anywhere but would be carried about, scattered through the infinite void' (*ad Hdt* §42).[24] In short, a finite number of atoms would be dotted about in an infinite space, and no cosmogonical collisions would ever occur. But why should a finite number of atoms not simply chance to congregate in one corner of infinite space? The answer is, I think, implicit in Aristotle's *Physics:*

> If the region outside the heavens is unlimited, so too, it seems, are body and the worlds; for why should it be here rather than here in the void? Hence mass is, if anywhere, everywhere (**238:** *Phys* 203b25–8).

Aristotle's ancient commentators ascribed this argument to Democritus, and modern scholars accept their judgment;[25] for the argument relies on the *Ou Mallon* Principle, and the principle is known to be Democritean. There is no reason for there to be atoms in one place rather than in another; but there are atoms in certain parts of the universe.

Hence atoms are scattered throughout the universe.' And we may, if we please, concoct a similar piece of reasoning for Epicurus: 'There would be no reason for a finite group of atoms to congregate in one place rather than in another. But they could not congregate everywhere; hence they would not congregate at all.'

That Democritus did hope to establish the infinity of atoms from the infinity of space by way of the *Ou Mallon* Principle is, I suppose, undeniable. I shall examine the Principle in a later chapter: here it is only necessary to say that the Democritean argument does not succeed.

(e) *Infinite variety*

There are infinitely many atoms, each solid, indivisible, immutable, eternal. How, then, does one atom differ from another? What further characteristics, by which they might be differentiated, do atoms possess? I have already mentioned size: atoms, being bodies, have a magnitude or size; and they differ in size from one another. Perhaps they exhibit an infinite variety of size; perhaps some are gigantic. At any event, even those authors who hold that all atoms are small, allow that they come in different sizes (e.g., **213**).

Having magnitude, the atoms also have shape, or (in the technical terminology of Abdera) *rhusmos* (e.g., *Met* 985b16=**67 A 6**); and atomic shapes differ: 'There belong to them every kind of shape and every kind of form…some are scalene, some hooked, some hollow, some convex—and they have innumerable other differences' (**213:** cf., e.g., Cicero, **67 A 11**). The differences are numberless: atomic shapes are infinitely varied.

Two arguments for the infinity of atomic shapes have survived. The first is transmitted by Aristotle:

> Since they [sc. Leucippus and Democritus] thought that the truth was in appearances, and the appearances were contrary and unlimited, they made the [atomic] shapes unlimited (**239:** *GC* 315b8=**67 A 9**).

The argument is echoed, with an important nuance, by Epicurus: 'It is not possible that so many varieties should come about from the same comprehended *(perieilêmmenôn)* [atomic] shapes. And in each shaping, the similar atoms are unlimited without qualification; but in their differences they are not unlimited without qualification but only incomprehensible *(aperileptoi)*' (*ad Hdt* §42). To explain the varied phenomena you require a multiplicity of atomic shapes, but not an infinity. The shapes are incomprehensibly, but finitely, many; they have a determinate number, even though we shall never determine it.

It is tempting to read Epicurus' view back into Leucippus: a literal infinity of atomic shapes is theoretically overgenerous; and our texts perhaps allow us to take the terms 'numberless' and 'unlimited' in a relaxed sense. But the Epicurean argument for the finitude of shapes may not have been available to the Atomists: 'the principles of things vary in a finite number of shapes. If that were not so, some seeds would thereby have to be of infinite bodily magnitude' (Lucretius, II. 479–82). This, presumably, was the argument which Epicurus used to show that atomic shapes were finite; and, as Lucretius

explicitly recognizes (II. 485), it hangs on the assumption of 'minimal parts': only if there are theoretically indivisible magnitudes will infinite shapes imply infinite sizes.[26] That assumption (as I have argued) cannot be shown to have been Abderite; nor, therefore, can we ascribe Lucretius' argument to the early Atomists.

Let us allow, then, that the Atomists posited an infinite variety of atomic shapes. The argument given in **239** for that hypothesis is a thunderingly bad one: if there are, literally, infinitely many differences in the phenomena, that at most requires that there are infinitely many different atomic structures underlying the phenomena. It does not require that the atomic *shapes* be infinitely various; indeed, it does not require that there be more than one atomic shape. How could the Atomists have failed to see that?

Now Simplicius offers a different reflexion: Leucippus 'hypothesized unlimitedly many eternally moving elements—the atoms—and the unlimited quantity of the shapes among them, because nothing is rather such than such…' **(236:67 A 8)**. The *Ou Mallon* Principle is here applied to atomic shapes: there are, mathematically speaking, infinitely many possible shapes; there is no reason why there should be atoms of shape *S* rather than atoms of shape *S′;* hence there are atoms of every shape. I shall look at the argument again when I discuss the Principle it incorporates. The argument is, I suspect, the official Abderite argument for an infinity of atomic shapes; and I am tempted to suppose that **239** does not contain an Abderite *argument* at all: having argued for infinity by the *Ou Mallon* Principle, the Atomists observed that an infinity of atomic shapes would amply explain the phenomenal infinity of the macroscopic world. Their observation was later misconstrued as an independent argument for infinity of shapes.

(f) *Atomic weight and motion*

Solid magnitudes will have a mass or weight *(baros);* and since the atoms differ in size, they will vary in mass. There is ample evidence that this was explicitly stated by the Atomists:

> Democritus says that each of the indivisibles is heavier in accordance with its excess [in size] (**240:** *GC* 326a9=**68 A 60**).

> The Democriteans, and later Epicurus, say that the atoms… have weight (**241:** Simplicius, **68 A 61**).

> Democritus distinguishes heavy and light by magnitude (**242:** Theophrastus, *Sens* §61=**68 A 135**).

Other equally grave witnesses can be called. Against them there is a single voice: Aëtius twice reports that

> Democritus says that the primary bodies…have no weight **(243:68 A 47)**.

These testimonies have aroused great controversy; orthodoxy now lies with Aëtius—the atoms do not have weight, at least not 'absolute' weight.[27] But I think it is evident that Aristotle and Theophrastus are preferable to Aëtius, who is confused by the whole question; and the thesis that atoms have weight or mass is an obvious corollary of the central tenets of atomism.

Mass goes with motion; and

> Leucippus says that…[the atoms] are infinite and always moving and that generation and change are continuous (**244:** Hippolytus, **67 A 10**);

according to Democritus, the atoms 'battle and are carried about in the void on account of their dissimilarity and the other differences aforesaid' (Aristotle, **213**). Aristotle once compares the atoms to the motes we see in a sunbeam (*An* 404a3=**67 A 28**); the image is developed at length by Lucretius in his account of the precosmic motion of the Epicurean atoms:

> For observe closely when the light of the sun is poured by the intruding rays through the darkness of the house: you will see many tiny bodies mingling in many ways through the empty space
>
> in the very light of the rays, and as though in eternal combat waging wars and battles, striving in companies and never giving pause, harried by constant meetings and partings. So you can guess from this what it is like when the principles of things
>
> are tossed about for ever in the vast void (**245:** II. 114–22).

Lactantius (*de ira* X. 9) ascribes the image to Leucippus: it was plainly a commonplace in atomist thought, and it is reasonably ascribed to the founder of the school. The atoms are shapes as gay and numberless as the motes that people the sunbeams.

If Leucippus gave an image, Democritus perhaps contributed a technical term:

> They…said that, moving by virtue of the weight in them, they move through the void which yields and does not resist them;[28] for they say that they *peripalaisesthai* (**246:** Simplicius, **68 A 58**).

Editors emend *peripalaisesthai* to *peripalassesthai;* they then restore the verb, or the noun *peripalaxis,* in other Democritean contexts; and they proclaim that *peripalaxis* is the technical term for atomic motions. Alas, most of the restorations are probably unjustified; and the meaning of *peripalaxis* is itself a matter of dispute (the standard translation is 'vibration'). The whole issue is unenlightening.[29]

However that may be, we have a moderately clear picture of atomic movement: in any area of space, numerous particles are dancing aimlessly, in various directions and at various speeds, sometimes colliding, sometimes moving unimpeded. What determines their different motions? Our sources give three answers: first, the atoms move 'by virtue of the weight in them' (Simplicius, **246**). That is repeated by several authorities (e.g., Hermias, **67 A 17;** Simplicius, **68 A 61**); and it appears to have roused objections from Epicurus (*ad Hdt* § 61=**68 A 61**). Aristotle, on the other hand, refers to 'dissimilarity

and the other differences' in order to explain atomic motion **(213),** and he marks shape as an important determinant of motion (*An* 404a4=**67 A 28**). Third, the doxographers speak of 'blows':

> Democritus says that by nature the atoms are motionless, and that they move by blows (**247:** Simplicius, **68 A 47**).
>
> Democritus says that the primary bodies…have no weight but move in the unlimited [void] by counter-striking *(allêlotupian)* (**248:** Aëtius, **68 A 47**).
>
> [Leucippus and Democritus] say that the atoms move by counter-striking, i.e. by hitting one another (**249:** Alexander, **67 A 6;** cf. Aëtius, **68 A 66**).

The commentators find difficulty here. Some distinguish two phases in atomic movement: the first occurs *before* the atoms have struck one another, and is free motion through space; the second occurs *after* a 'counter-striking' and is compelled motion. But there is no textual evidence for a period in which the atoms roamed freely, untouched by their fellow occupants of space; and if the atoms have been moving for all eternity, it is hard to imagine why there should ever have been such a period.

Nor do our sources provide any genuine difficulty. Aëtius' denial of weight to the atoms may be dismissed (above, p. 365); the remaining testimony gives a coherent picture: in themselves, atoms are indeed motionless; that is to say, they would not be moving had they not collided with other atoms and so been jolted into motion. ('How, then, did the atomic motion ever *begin*?' That is a tale for a later chapter.) But if collision is the propellant cause of motion, the speed and direction of an atom's travel is determined by its weight and its shape—more precisely, by the weight, shape, and anterior motions of the colliding bodies. Throw a stone at a cat, and its rebounding path will be determined by its own weight, shape, and anterior motion, and by the corresponding properties of the cat: the stone rebounds because of its 'counter-striking' the cat; the trajectory of its rebound is determined by weight and shape. No doubt it is wrong to construct the dynamics of atomic motion from observations of macroscopic motion through air; and Epicurus' account of atomic motion differs radically from the account I have ascribed to Democritus. For all that, the early atomist account is rational, coherent, and sane: if it is wrong in fact, at least it was intelligently constructed.

(g) *Atomic indifference*

> They say that there are these three differences: shape, order and position. For they assert that existents [*to on*, i.e. the atoms] differ only in *rhusmos* and *diathigê* and *tropê;* of these, *rhusmos* is shape, *diathigê* order, and *tropê* position. For *A* differs from *N* in shape; *AN* differs

> from *NA* in order; and *N* differs from *Z* in position (**250:** Aristotle, *Met* 985b13–19=**67 A 6**).[30]

Elsewhere Aristotle uses a similar analogy: in explanation of how the rearrangement of a group of atoms can produce radically different macroscopic results, he says that 'tragedy and comedy are put together from the same letters' (*GC* 315b15=**67 A 9**). Scholars infer, with some plausibility, that the alphabetical analogy was employed by the Atomists themselves (cf. **68 B 18b**–**20**).

Aristotle's three differences make a clumsy triad. First, they are not the only, nor even the only important, differences among atoms: atoms also differ in size, in weight, and in velocity. Second, difference in *diathigê* and *tropê* is a relation among groups of atoms and not among individual bodies; that is evident in the case of *diathigê* and only slightly less so for *tropê*—the letter *N* has, in itself, no *tropê* in space. I suspect that Leucippus or Democritus saw that the letter analogy would neatly illustrate *rhusmos, diathigê* and *tropê,* and, pleased by the discovery, overlooked its minor awkwardnesses. However that may be, it is plain that *diathigê* and *tropê* are characteristics of groups of atoms and not of individual corpuscles.

The doxographers several times say that atoms are *apoioi* (Plutarch, **68 A 57;** Aëtius, **68 A 124; 125**). *Apoios* usually means 'qualityless' *(a+poiotês),* but it can mean 'inactive', 'inert' *(a+poiein).* Most of the ancient sources take it in its former sense: Galen says that the atoms are all 'small bodies, without qualities' **(68 A 49);** Plutarch gives as an illustration of *apoios* 'colourless' **(68 A 57)**. Then, uneasy with the bland assertion that atoms are unqualified, our sources explain that this means 'without *sensible* qualities' (cf. Aëtius, **68 A 124;** Sextus, **68 A 59;** *Pyrr Hyp* III. 33; and see Epicurus, *ad Hdt* §54).

A passage from Aristotle seems to take the other road, implying that atoms are *apoioi* in the sense of impotent:

> It is necessary to say that each of the indivisibles is both impassive *(apathes)*…and productive of no affection *(pathos)*—for it can be neither hard nor cold (**251:** *GC* 326a1–3).

Atoms are impassive and inactive, equally incapable of receiving and of giving affection. Some scholars construe inactivity here as the inability to affect other atoms: inactivity then follows immediately from impassivity; for if atoms cannot be changed, then no atom can change any atom. That is a part of the story (cf. 326all); but Aristotle means to assert not merely that atoms cannot affect other atoms, but that they cannot be 'hard or cold' or anything else—in short, he wants to assert that they are *apoia* in the sense of 'lacking (sensible) qualities'. And his argument is not hard to distil. It relies upon the Principle of Synonymy (above, pp. 88, 119); if *a* is active, *a* can bring it about that *b* is *F;* but if *a* can bring it about that *b* is *F* (where *F* is a sensible quality), then *a* is *F*. In short, Aristotle means to say, in the concise and somewhat ill-humoured passage at 326a1–24, that atoms lack sensible qualities and, consequently, active powers.

If atoms lack sensible qualities, they cannot differ one from another in respect of sensible qualities. Aristotle takes the point in the same crotchety passage of the *GC:* he

asks: ‘again, do all those solids [i.e. the atoms] have one nature, or do they differ one from another—as it might be, some being fiery, others earthen in mass?’ (326a29–31). And he answers:

> They say that they have a single nature—as it might be, each being a separate bit of gold (**252:** *Cael* 275b31=**67 A 19**; cf. *GC* 326a17).[31]

Dalton, who is often hailed as the founder of modern atomism, disagreed: his atoms are diverse; they are indivisible particles of different chemical stuffs. Daltonian atomism is familiar from schoolboy chemistry, where we may incautiously take such a formula as ‘H_2O’ to indicate the amalgam of two atoms of hydrogen with one of oxygen. Atoms of hydrogen have those powers or sensible qualities which characterize the gas hydrogen; and that fact distinguishes them from atoms of oxygen, of chlorine, of iron, and of all the other chemical elements. This chemical atomism, as I may call it, may be contrasted with a physical atomism, according to which the chemical differences between oxygen and hydrogen do not exist at the corpuscular level: there are not atoms of oxygen and atoms of hydrogen, any more than there are atoms of sugar or atoms of soap. Atoms are bits of stuff, having all the characteristics of matter and none of the characteristics specific to any particular type of matter. ‘Body, common to everything, is the principle of everything, differing in its parts by size and shape’ (*Phys* 203a34–b2=**68 A 41**). Davy championed physical atomism and the unity of matter; Dalton, chemical atomism and the irreducible diversity of matter: the unitarian view, which had served in an Aristotelian guise as the foundation of alchemical hopes, in the end triumphed.

Democritus is no Daltonian; but his atoms are not, strictly speaking, ‘indifferent’ or *adiaphoroi:* they differ intrinsically in shape and size, and as a consequence in weight and motion. In a pure physical atomism, each atom would be precisely similar to every other; there would be one atomic shape and one atomic size; macroscopic diversities would be explained solely in terms of differences in atomic structures and not in terms of differences among the components of those structures.

(h) *The status of sensible qualities*

Atoms are not coloured; they have no taste and no smell. Did the Atomists simply deny the reality of sensible qualities? Did they offer any account of the qualities of macroscopic bodies? Did they really mean to assert that atoms lack *all* sensible qualities?

It is clear that the doxographers are speaking loosely when they say that the atoms have no sensible qualities: shape, size and motion are, after all, sensible qualities; and if the atoms are too small for their qualities to be discerned, that does not deprive those qualities of their sensible nature. Moreover, it appears that the atoms had a further and indubitably sensible property: temperature. Aristotle is scathing here: ‘Yet it is absurd just to ascribe heat to round shapes’ (326a3–5); ‘No atoms have any sensible qualities—except that round atoms are hot’ (cf. *Cael* 303a12–14=**67 A 15**). Theophrastus expands the point: it is absurd, he says, for Democritus

> to make intrinsic natures of heavy and light and hard and soft… but to make hot and cold and the rest relative to sensation—and that though he says frequently that the shape of the hot is spherical (**253:** *Sens* §68=**68 A 135**).

On the one hand, heat is treated alongside other sensible qualities and so should not belong to the individual atoms (cf. **B 9; B 117**); on the other hand, heat is associated with spherical atoms, because spherical atoms move most easily (Aristotle, *An* 404a7=**67 A 28**), and easy movers cut and burn (*Cael* 303b32).

The criticism does not apply to Leucippus, who offered a different account of heat (Simplicius, **67 A 14**). Perhaps the criticism is in any case inapposite; perhaps the Atomists never intended to distinguish between sensible and non-sensible qualities and to deny their atoms the former; perhaps they had some other criterion for determining whether or not a quality was of a type to be possessed by an atom. Here I introduce one of the most celebrated of Democritean sayings. It is transmitted to us in several forms; and indeed it may have been stated in different forms by Democritus himself. I quote Plutarch's version; for although his text is corrupt, his version is the fullest and the best:

> By convention *(nomôi)* is colour, and by convention sweet, and by convention [every] combination *(sunkrisin),* [but in reality *(eteêi)* the void and atoms] (**254:** *adv Col* 1110 E).[32]

Democritus means to draw an ontological distinction between 'atoms and void' on the one hand, and certain other things on the other; and he intends to assign-'atoms and void' a superior ontological rank to those other things. So much is clear: the rest, I think, is more puzzling than is usually allowed.

In all our sources other than Plutarch, the list of 'conventional' items is a list of qualities (hot, cold, bitter, sweet, colour); and Diogenes Laertius says simply that 'qualities *(poiotêtes)* are by convention' (IX.45=**A 1**). Diogenes is speaking loosely: I assume that we may add to the *eteêi* side of the great divide a list of atomic qualities: shape, size, weight, motion. And I assume too that the distinction between 'conventional' and 'real' qualities gives the criterion for atomic qualities: a quality is non-atomic if it is 'conventional', if it exists *nomôi.* There is no explicit suggestion that *nomôi* qualities are sensible qualities; and the thesis that atoms lack sensible qualities has already been judged erroneous. What, then, is it for a quality to be 'conventional'? (A 'combination' *(sunkrisis)* is not a quality: I return to that word in a later context, below, pp. 141–5.)

The seventeenth-century corpuscularians made much of a distinction between 'primary' and 'secondary' qualities. The classic exposition of the distinction is found in Locke's *Essay,* in a chapter where Locke, as he admits, is more than usually indebted to the scientists, and in particular to Boyle. Locke introduces the distinction as follows: 'Qualities thus considered in Bodies are, First such as are utterly inseparable from the Body, in what estate soever it be; such as in all the alterations and changes it suffers, all the force can be used upon it, it constantly keeps; and such as Sense constantly finds in every particle of Matter, which has bulk enough to be perceived, and the Mind finds inseparable from every particle of Matter, though less than to make itself singly be

perceived by our Senses…. These I call *original* or *primary Qualities* of Body' (*Essay* II. viii. 9).

Notice first, that Locke does not talk of primary qualities *simpliciter*, but of primary qualities of body (elsewhere he mentions the primary qualities of spiritual substances (II. xxi. 73; xxii. 17–18)—and he might consistently have singled out primary qualities of any kind of thing); second, that the distinction between primary and secondary qualities is not logically tied to a paniculate or atomist theory of matter; and third, that primary qualities 'of body' are properties of pieces of stuff and not of stuff *simpliciter*.

Thus we may say, generally:

(D1) *Q* is a primary quality of F s if and only if necessarily any *F* has *Q;* and, particularly:

(D2) *Q* is a primary quality of bodies if and only if necessarily every body has *Q*.

Primary qualities, in short, are essential properties (cf. II. iv. 1).

Secondary qualities are introduced as follows: '2*dly*, Such *Qualities*, which in truth are nothing in the Objects themselves, but Powers to produce various Sensations in us by their *primary Qualities*, *i.e.* by the Bulk, Figure, Texture and Motion of their insensible parts, as Colours, Sounds, Tastes, *etc*. These I call *secondary Qualities*' (*Essay* II. viii. 10). Locke is trying to say too much at once; let me be rudely dogmatic and say what I think Locke should have said. First, he wants a definition of 'secondary quality'; and he needs:

(D1*) *Q** is a secondary quality of *F*s if and only if some Fs have *Q** and *Q** is not a primary quality of *F*s.

Second, he wants to advance a number of theses about the secondary qualities of bodies; these include the following: secondary qualities are not 'real'; they are powers; they are relational; they are mind-dependent; and their presence in objects is explicable in terms of the primary qualities of their component corpuscles.

The last point requires a little elaboration. Consider, first, the property of being cubic. That, clearly, is a secondary quality of bodies; but it stands in a special relationship to the primary quality of figure or shape: *being cubic* is, in a convenient jargon, a determinate of the determinable property *being shaped*. Call qualities which are thus determinates of primary qualities 'proper' qualities. Then Locke's thesis is this: corpuscles, or atoms, have no properties apart from primary qualities and proper qualities of body; macroscopic bodies have secondary qualities, but those qualities are all explicable by way of the primary and proper qualities of the corpuscles which constitute the macroscopic bodies.

It is often suggested that Democritus' distinction between *nomôi* and *eteêi* qualities is the first version of the distinction between primary and secondary qualities: *eteêi* means 'real' or 'primary'; and if *nomôi* does not exactly mean 'secondary', nevertheless *nomôi* qualities are secondary qualities. That view is clearly mistaken (sphericality, say, is a secondary quality, but it is not *nomôi*); but it is on the right road. In its place I suggest the following thesis:

(D3) Q is *eteêi* if and only if *Q* is either a primary or a proper quality of bodies.

I do not mean that the Atomists explicitly embraced (D3)—there is no trace of any such defintion in the doxography; but I think that (D3) is the thesis which best explains the atomist attitude to atoms and qualities.

The list of atomic properties—duration, solidity, mobility, mass, shape, size—is close enough to the Lockean list of primary qualities. And it is not implausible to imagine that Democritus ascribed these qualities to atoms just because he thought them essential to bodies.

Moreover, the Atomists thought that the secondary qualities of macroscopic objects are explicable in terms of the properties of their atomic constituents.

> The elements are qualityless,…and the compounds from them are coloured by the order and shape and position [of the atoms] (**255:** Aëtius, **68 A 125**).
>
> White and black, he says, are rough and smooth; and he reduces the savours to the [atomic] shapes (**256:** Aristotle, *Sens* 442b11= **68 A 126**).

A long passage in Theophrastus' *de Sensu* is devoted to Democritus and it contains numerous Democritean accounts of the sensible qualities; I quote a short (and controversial) passage:

> Sour taste comes from shapes that are large and multi-angular and have very little roundness; for these, when they enter the body, clog and blind the veins and prevent their flowing—that is why the bowels too come to a stand. Bitter taste comes from small, smooth, rounded shapes whose periphery does have joints; that it why it is viscous and adhesive. Saline taste comes from large shapes which are not rounded or scalene but angular and many-jointed (he means by scalene those which interlock and combine with one another)—large, because the saltiness stays on the surface (for if they were small and struck by those surrounding them they would mingle with the universe); not rounded, because what is saline is rough and what is rounded is smooth; not scalene, because it does not interlock—that is why it is friable (**257:** §66=**68 A 135**).[33]

In that account of gustatory qualities, and throughout Theophrastus' report, it is the shapes of individual atoms which account for macroscopic qualities. Shape is far more important in the atomism of Democritus (who significantly called his corpuscles *ideai* or 'shapes') than in modern atomism, where it is the interrelations and relative locomotions of the constituent atoms which are primarily responsible for macroscopic phenomena. But fundamentally Democritus and Locke are at one: atomic qualities underlie and explain macroscopic qualities.

Why suppose that atoms have no secondary qualities? First, the atoms, being physical bodies, are logically bound to possess a certain set of properties: solidity, size, shape, etc. Then let us hypothesize that those are *all* the properties they possess, and attempt to explain the phenomena in terms of them. The hypothesis is maximally economical: if it is successful in explaining the phenomena, then we shall certainly have no reason to ascribe any secondary qualities to atoms, and hence should not do so. Moreover, it may well be that an analysis of secondary qualities will show that some or all of them could not in fact belong to atoms. Suppose that elasticity is explained in terms of density, i.e. in terms of a certain distribution of atoms and void in an atomic

conglomerate; then clearly no single atom can be elastic. Suppose that sourness is explained in terms of the effect of a mass of corpuscles on the gustatory organs; then clearly no single corpuscle can be sour.

The most perplexing part of Locke's account of secondary qualities is his assertion that they are not real: did the Atomists adumbrate that part of the account too? and can we make any sense of it? 'Improper secondary qualities are not *eteêi:* they are therefore unreal.' An easy gloss suggests itself: if improper secondary qualities can be accounted for by way of primary and proper qualities, then a complete account of the real world need mention no improper secondary qualities at all; for every fact expressible by a sentence of the form 'Macroscopic object *M* has *Q**' is equally, and more fundamentally, expressible by a sentence of the form 'Atoms A_1, A_2,…, having Q_1, Q_2…, are arranged in pattern *P*'.

But *eteêi contrasts* with *nomôi;* and the contrast suggests a further, and equally Lockean, sort of 'unreality'. The classical contrast with *nomôi* is *phusei*, 'by nature'; and the doxographers deploy the contrast:

> The others say that perceptible things are by nature, but Leucippus and Democritus…[say that they are] *nomôi* (**258:** Aëtius, **67 A 32**).

> By nature nothing is white or black or yellow or red or bitter or sweet (**259:** Galen, **68 A 49**).

This, however, does not take us far: we have still to interpret *nomôi*. It is doubtless 'conventional' in some sense that we call sweet things 'sweet' and that the Greeks called them *glukea;* but it is no 'convention' that ripe plums taste sweet and green plums taste sour, nor can Democritus have thought that it was.

Sextus offers a more appealing gloss:

> I.e., perceptible things are thought *(nomizetai)* and believed to exist, but they do not exist in truth (**260:** *adv Math* VII. 135= **68 B 9**).

Galen hints at the same thought:

> Things are thought *(nomizetai)* by men to be white and black and sweet and bitter and all the rest, but in truth there is nothing but [atoms and void] **(261:68 A 49)**.

Let *Q** be an improper secondary quality of body: then *Q** exists *nomôi*, i.e., people think that some things have *Q** but in truth none do. We might compare Democritus' view on 'mixture' or *krasis:*

> He says that in truth things simply are not mixed, but that what is thought *(dokousan)* to be a mixture is a close juxtaposition of bodies which each preserves its own appropriate nature (**262:** Alexander, **68 A 64**).

Things seem to be mixed; they are not—and a microscopic inspection would reveal the fact. Similarly, things seem to be red or warm or bitter or soft; they are not—and a microscopic inspection would reveal the fact.

But that will not do. It is simply absurd to say that fire is only *thought* to be hot, grass only *thought* to be green, sugar only *thought* to be sweet. And what are we to make of Democritus' laborious and detailed accounts of such qualities as heat, greenness and wetness if those qualities are never actually instantiated? Aristotle unwittingly brings home the absurdity:

> That is why he [sc. Democritus] says that colour does not exist—for things are coloured by position *(tropêi)* (**263:** *GC* 3l6a1= **68 A 123**).

'Grass is green in virtue of such and such an atomic structure; *ergo* grass is not green.' Could there be a crasser inference than that?

A better gloss on *nomôi* is to hand: improper secondary qualities are not 'natural' because they are mind-dependent:

> [They are] *nomôi,* i.e., they are in belief and by virtue of our affections (**264:** Aëtius, **67 A 32**).

> For *'nomôi'* means the same as 'in thought *(nomisti)'* or 'relative to us', not in virtue of the nature of the objects (**265:** Galen **68 A 49**).

The view is found in Theophrastus: Democritus says that

> Of none of the other sensible objects is there a nature *(phusis),* but they are all affections of perception, as it alters and imagination comes from it; for there is no nature of the hot and the cold, but the shape *(schêma)* alters and works the change in us (**266:** *Sens* §63=**68 A 135**).

'Sweetness and Whiteness', as Locke puts it, 'are not really in Manna' (II.viii. 18); they are not *in* manna, because they are relations between manna and the mind of some sentient creature. Thus 'there would …be no more Light, or Heat in the World, than there would be Pain if there were no sensible Creature to feel it, though the Sun should continue just as it is now, and Mount *Ætna* flame higher than ever it did' (*Essay,* II.xxxi.2).

Qualities divide into two groups: those which are *eteêi* or real, and those which are *nomôi* or mind-dependent: 'square', 'heavy', 'at rest' name intrinsic properties of objects; 'smooth', 'red', 'sweet' are, as Sextus put it 'names of our own feelings' (*adv Math* VIII. 184). Atoms, the fundamental items of the world, possess only real qualities; and those qualities are either primary qualities, qualities which every body as a matter of necessity possesses, or else proper qualities, determinate forms of primary qualities. All improper secondary qualities are explicable by way of *eteêi* qualities; and the explication reveals that they are all mind-dependent.

I shall not attempt to assess the merits of that complex thesis; but it is perhaps worth indicating what any assessment must look to. First, there is the distinction between *eteêi*

and *non-eteêi* qualities itself. It is, I think, plausible to believe that the class of *eteêi* qualities can be accurately defined by way of the notion of a primary quality; and it is plausible to believe that the *eteêi* properties of body will constitute a scientifically important sub-class of the class of bodily qualities.

Second, there is the Abderite list of *eteêi* qualities: it needs to be asked just what qualities satisfy the definition of *eteêi*. And it may well be that this question proves unexpectedly difficult; at any event, philosophers have not agreed on any list of primary qualities of body.

Third, there is the status of *non-eteêi* qualities. Are all these qualities in fact explicable by way of *eteêi* qualities? And would such an explication yield a logical or a causal dependence between *eteêi* and non-*eteêi* qualities? (It is often noticed that Locke fails to distinguish clearly between a causal thesis, that secondary qualities are *produced* by primary qualities, and a logical thesis, that secondary qualities are *analysed* into primary qualities; the observation, which I have stated crudely, leads to some difficult and intriguing questions.) And, finally, are non-*eteêi* qualities really mind-dependent? And is that dependency logical or causal?

(i) *The philosophy of Abdera*

The Abderite philosophy of matter began from the notion of *being*, of primary beings, substances or *ousiai*. Substances, they held, are solid and unitary bodies, ungenerable, indestructible, immutable, indivisible, everlasting. These basic items of the physical world are infinitely numerous and exhibit an infinite variety of shape and size; they are in constant motion, and their collisions and colligations form the macroscopic and changing world of phenomenal reality. The qualities they possess are those qualities which every body logically must possess, or at least determinate forms of those qualities.

The phenomenal world reveals a vast range of qualities not included in the list of atomic characteristics. But those qualities exist only ‘by convention’: they are mind-dependent, and their existence is to be explained in terms of the properties of the fundamental atomic traits. That assertion raises various difficult questions; and the value of the Abderite theory remains uncertain until they are answered. But it is, I hope, very plain that the theory began a line of thought whose influence upon philosophy and upon science was of unparalleled consequence.