Aristotle: Critic or Pioneer of Atomism?

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Aristotle is typically construed as a critic of atomism. He was indeed a critic of atomism of the extreme kind formulated by Democritus, according to which bulk matter is made of nothing other than unchangeable pieces of universal matter possessing shape and size and capable of motion in the void. However, there is a weaker kind of atomism involving the assumption that macroscopic substances have least parts which have properties sufficient to account for the properties of the bulk substances that they are least parts of. Insofar as atomism has been vindicated by modern science, it is the weaker version of atomism that has proved to be profitable. The beginnings of the weaker version of atomism are to be found in Aristotle. Far from being an opponent of atomism, there is a sense in which Aristotle was one of its pioneers.

Introduction

Aristotle is typically cast as a critic of atomism. If atomism is interpreted in its strict Democritean sense, as claiming that the universe in its entirety is composed of unchanging units characterised solely in terms of their shape, size and oneness and moving and colliding in the void, then Aristotle was indeed an opponent of atomism.

However, if atomism is interpreted in a less strict sense, to mean that bulk matter is composed of discrete entities bearing properties that are sufficient to account for the properties of the whole of which they are components, then Aristotle was not an opponent of atomism. Indeed, he was the originator of some of the key ideas that were to inform the weaker version of it.

It is important to appreciate that, insofar as atomism was incorporated into experimental science, and insofar as it has been vindicated by modern science, it is the weaker version of atomism that is at issue. John Dalton's chemical atomism, for example, introduced early in the nineteenth century to explain such things as the law of constant proportions of elements in compounds, was directed at explaining a range of chemical phenomena and not matter or change in general. What is more, Dalton's atoms possessed properties, such as the ability to combine with atoms of

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other substances with greater or lesser facility to form compound atoms, which enabled them to fulfil their chemical function. In modern science a specific mass and charge are attributed to electrons, and this is done, not on the basis of some general account of being and change, but as the result of experiments involving the deflection of cathode rays by electric and magnetic fields.

Raffaello Sanzio, 1509, *The School of Athens* (detail): Plato and Aristotle.

If we accept the terms of the debate engaged in by Parmenides, and, for instance, accept that the notion of being-as-such makes sense and that there is only one kind of it, then the atomism proposed by Democritus has merit. It shows how change in general can be reconciled with the Parmenidean conception of being. However, it proved difficult to develop the theory beyond this general result by adding specific atomic explanations. The major problem with Democritus's atomism stems precisely from its degree of generality. It is quite remote from specific phenomena that it might be expected to explain. Phenomena such as the functioning of the senses, gravity and elasticity were to be explained by going directly to some postulated atomic mechanisms that lie well beyond what was empirically accessible. It should not be surprising that the proposed mechanisms were fanciful and inadequate.

Aristotle, although he was quite capable of a high degree of abstraction, evident in the *Metaphysics* for example, was more empirically inclined. In the *Prior Analytics* (I 30, 17–22) he wrote:

> Consequently, it is the business of experience to give the principles which belong to each subject. I mean for example that astronomical experience supplies the principles of astronomical science: for once the phenomena were adequately apprehended, the demonstrations of astronomy were discovered. Similarly with any other art or science.[1]

As we shall see, the germs of a weak version of atomism that are to be found in Aristotle grow out of quite specific empirically grounded issues.

Zeno's Paradoxes and the Continuum

Democritus and Aristotle both needed a response to paradoxes of the kind proposed by Zeno to indicate that change and motion are impossible. A paradox stemming from the notion of infinite divisibility of immediate relevance to atomism goes as follows. Suppose some finite whole is infinitely divided. Do the infinity of parts that result from the division have a finite size or not? If they do, then an infinite size will result from their combination. If they have zero size then they will yield zero size when combined. In neither case is the finite size of the original whole recovered.

Democritus can be seen as having blocked the path to this paradox by denying the possibility of infinite division. Division must stop at the point where indivisible atoms are reached. Aristotle was right to insist that such a move does not in fact solve the paradox. The paradox does not hinge on the possibility of infinite physical division. It arises in the context of what might be called conceptual division also. Democritus's atoms do not have physical parts but they have conceptual parts. They have a surface that is distinct from their interior and some have hooks that

1 As translated by Richard McKeon (1941). All other quotations from Aristotle's works are from this source unless otherwise specified.

protrude. One can conceptually divide an atom into parts, and once it is admitted that such a conceptual division can proceed indefinitely then the paradox recurs once the question of the size of the parts arising from an infinite division is raised. Aristotle was right to identify the problems raised by Zeno as conceptual ones involving the divisibility of lines, surfaces and volumes as abstractions from the shapes and trajectories of physical objects. His response was the construction of what was, in effect, the first mathematical theory of the continuum.[2]

Infinite divisibility is a defining feature of a continuum for Aristotle. However, his defence of such a notion should not be interpreted as a denial of atomism. The latter, interpreted as a physical theory, puts a limit on the physical divisibility of a physical whole. Aristotle himself endorsed theories that involved such limits, and he even opposed the notion of infinite physical divisibility on the grounds that it is unrealisable in principle since it involves the actualisation of an infinite number of steps. Aristotle devised a mathematical theory of the continuum and also contemplated atomic theories in the weak sense as we shall see below.

Change in Aristotle

For Aristotle, the degree of variety and activity manifest in the world cannot be reconciled with the stark ontology involved in Democritus's picture of inert atoms moving and colliding in the void. A chicken, a poison and a stone are alike insofar as they are material things but they differ widely in their properties. These were due to the form superimposed on the material substratum in each case in Aristotle's system. Individual items in the world are what they are by virtue of the way they can act, react and interact and, in the biological world, grow, procreate and die. By attending to the kinds of things that there are and the kinds of ways in which they behave Aristotle was led to distinguish between various kinds of being and change.

Of particular relevance to a discussion of Aristotle's contribution to atomism is his classification of types of change in Book 1 of *On Generation and Corruption*. The type of change involved in generation and corruption, such as the conception and birth or death and decay of an animal is different from mere alteration such as that involved when a chicken grows fat or an autumn leaf turns brown. The difference identified by Aristotle lies in the fact that for generation and corruption, unlike for alteration, there is no identifiable material substratum that persists. Intermediate between these two cases is what Aristotle calls combination. An example is the formation of bronze from copper and tin. The properties of bronze are qualitatively distinct from those of copper and tin, so the copper and tin do not persist in the bronze in any straightforward sense. On the other hand, the tin and copper

2 For a sympathetic account of Aristotle's theory of the continuum and its ability to solve Zeno's paradoxes see Feyerabend (1983).

persist in some sense because they are recoverable from bronze. Aristotle put his finger on what was to become a central issue in chemistry, the sense in which elements persist in compounds. Aristotle's achievement should not be over-estimated. There were very few examples of what we now refer to as chemical change available to Aristotle. Alloys presented him with just about his only examples and it is ironic that these are not even compounds from a modern point of view. Nevertheless, scholastics were able to draw on these and other writings of Aristotle to construct the beginnings of an atomic chemistry.

Natural Minima

A homoeomerous substance is one whose parts are also a sample of that substance. Water is homoeomerous because a part of a sample of water is still water. An apple tree is not homoeomerous because a part of it is not itself an apple tree. At least the germs of the idea that homoeomerous substances have least parts can be found in Aristotle. The idea emerges in a context where Aristotle is taking issue with Anaxagoras. The latter had sought to explain how, for instance, water and bread can be changed into flesh and blood, by arguing that portions of water or bread, however small, contain the seeds of flesh and blood. Indeed, it was Anaxagoras's view that seeds of everything exist in everything. Aristotle (*Physics*, 1, 4, 187b, 25–35) takes issue with the claim, involved in Anaxagoras's position, that substances are composed of an infinite number of infinitely small seeds.

> Hence, since every finite body is exhausted by the repeated abstraction of a finite body, it seems obviously to follow that everything cannot subsist in everything else. For let flesh be extracted from water and again more flesh be produced from the remainder by repeating the process of separation: then, even though the quantity separated out will continually decrease, still it will not fall below a certain magnitude. If, therefore, the process comes to an end, everything will not be in everything else (for there will be no flesh in the remaining water); if on the other hand it does not, and further extraction is always possible, there will be an infinite multitude of finite equal particles in a finite quantity — which is impossible.

Here the least parts of flesh are atoms in the sense that they are indeed least parts. However, they are not Democretian atoms because they retain the properties of flesh.

There were no clear-cut arguments for the existence of what were to become known as "natural minima" of homoeomerous substances, but there are hints of such arguments to be found in Aristotle. One of them is apparent in the above quotation, where Aristotle indicates that an infinite number of finite parts is an impossibility. The other alternative, that the parts have no size, is ruled out by Aristotle's theory of the continuum which involves the insistence that, for example, a point is not part of a line. A second argument involves the recognition that animals, made up of flesh, bone and so on, exist only in a finite range of sizes. Mice that are as small as a grain of sand or as large as a house do not occur. The inference (*Physics*, 1, 4, 187b, 18–21) seems to be that the parts of flesh etc must be similarly confined to a finite range of sizes so that there must be a least size. Perhaps the following is what Aristotle had in mind. If the substances making up a mouse were strictly continuous then there seems to be no reason why a scaled-down version of a mouse should not also be a mouse, however great that scaling down be. However, least parts set a limit to the scaling down. One cannot make a mouse as small as a grain of sand out of least parts of flesh, bone and so on any more than one can make a tiny dolls house out of house bricks. A third hint of least parts appears in the context of chemical change, developing the idea that, in order to combine, substances need to be in contact. Aristotle notes (*On Generation and Corruption*, 1, 10, 328a, 34–5) that substances "combine more freely if small pieces of each of them are juxtaposed".

It would be an exaggeration to claim that Aristotle proposed an atomistic account of chemical reactions involving the fusing of least parts of combining substances to form least parts of the product. Nevertheless, such a theory was developed by those who came after him, from Averroes in the twelfth century to Daniel Sennert in the seventeenth century. These thinkers developed an account of chemical combination taking place "per minima". In doing so they presented themselves as developing Aristotle's own thought.[3]

Atoms and Alchemy

Perhaps the first hints of the incorporation of atomism into experimental science take place in late medieval alchemy. The fact that the alchemists made extensive use of an atomistic theory of matter, in the weak sense, is clear from the highly influential *Summa Perfectionis* of pseudo-Geber, now known to have been written by an Italian, Paul of Toranto in the late thirteenth century. As William Newman (1991) has shown, this work contains a matter theory which is atomistic in the sense that it involves, for example, reference to particles of substances combining per minima to form compounds and explanation of the separation of substances by sublimation using the assumption that a small amount of heating will drive off a substance composed of fine particles leaving those composed of courser particles behind. These particulate theories were influential beyond the confines of alchemy. They influenced the natural minima theory of Daniel Sennert which in turn influenced the corpuscular chemistry of Robert Boyle, as Newman (1996) has shown.

A major source of the atomistic, or corpuscular, speculations in alchemical matter theory, in addition to Aristotle's gestures towards natural minima, was Book 4

[3] For details of medieval extensions of Aristotle's atomism see A. van Melsen (1960:41–88) and N. E. Emerton (1984:77–125).

of *Meteorology*, perhaps the most empirically orientated of all of the Aristotelian corpus, although it is not certain that Aristotle himself was the author. In Book 4 there are various hypotheses about the existence of pores in matter to explain absorption, compressibility and combustibility. As well as these references to the microstructure of matter there is at least one explicit reference to corpuscles, or atoms in my weak sense.

> A thing is viscous when, being moist or soft, it is tractile. Bodies owe this property to the interlocking of their parts when they are composed like chains, for then they can be drawn out to a great length and contracted again. Bodies that are not like this are friable (Meteorology. IV, 387a, 11–14).[4]

I do not wish to make too much of the corpuscular, or weak atomist, tradition and the debt it owed to Aristotle because it was not particularly productive. But I do wish to conclude by stressing two points. Firstly, atomism of the strict Democritean kind was implausible and explanatorily impotent in ways that could be appreciated by the Ancients and most of Aristotle's criticisms of it were well founded. Secondly, if atomistic theories were to make any headway, then it was necessary to ground them in observation and experiment in some way to help establish what kinds of atoms exist with what kinds of properties. It was Aristotle who made a serious start to that endeavour rather than relying on a priori speculation.

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