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Leucippus and Democritus on Like to Like and ou mallon

Abstract: The central issue for this paper is whether for Leucippus and Democritus,¹ the like to like principle, which is critical to cosmos formation once a vortex forms, operates outside of the vortices.² Should we consider like to like in the early atomists to be akin to a ‘fundamental force’, with a universal application, as some commentators have suggested?³ Or should we rather consider it to be a sorting effect generated by certain types of motion, occurring only when those types of motion occur? As a matter of detail this is interesting in itself and it also bears on several important interpretive issues for Leucippus and Democritus. What are the intrinsic properties of atoms, if any, beyond their size and shape? Is the initial formation of a vortex a matter of necessity or a matter of chance? Is what happens in a cosmos a matter of necessity or chance? Although not immediately obvious, this will also raise issues concerning to what extent Leucippus and Democritus are committed to the principle of sufficient reason.

I will argue that there are good theoretical and textual reasons to believe that like to like occurs only in the vortices. I will also argue that just as there are no preferred sizes and shapes for atoms for Leucippus and Democritus, no preferred distribution of the atoms in the void and there are no preferred times or places for vortex/cosmos formation either. This I suggest gives Leucippus and Democritus a coherent and interesting position relative to Parmenides. Where Parmenides denies multiplicity and raises sufficient reason issues about the time and place of cosmos formation, Leucippus and Democritus assert multiplicity but without preferred shapes and sizes of atoms and cosmogony without preferred times and places of cosmos formation. Of importance here will be an interesting paradox in cosmogony – if we begin with a uniform entity or

1 In line with modern practice, I make no attempt to differentiate the views of Leucippus and Democritus, who I also refer to as the ‘early atomists’ in distinction to Epicurus and his followers. My thanks to Prof. Steven Tigner, Hugh McKenzie, an anonymous referee and the audience at the Institute of Classical Studies, University of London seminar series on Being in Early Greek Philosophy for the for their helpful comments on this paper.

2 A note on terminology. For Leucippus and Democritus I use the term ‘cosmos’ to refer to a single system of earth/sun/moon/planets/stars (plural ‘cosmoi’) while I use the term ‘universe’ to refer to the void and everything in it, including all the cosmoi.

3 C. C. W Taylor, *The Atomists: Leucippus and Democritus*. Toronto: University of Toronto Press, 1999, p. 194.

uniform distribution of entities how does a non-uniform state such as a cosmos arise, while if we begin with a non-uniform entity or non-uniform distribution of entities how do we explain this non-uniformity?⁴

Keywords: Leucippus, Democritus, Like to Like, ou mallon, reason

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Let us begin with the fullest account we have of early atomists cosmogony, given by Diogenes Laertius:

Leucippus holds that the whole is infinite... part of it is full, and part void... from these innumerable cosmoi come to be and are dissolved into these again. The cosmoi are generated in this manner. By cutting off from the infinite many bodies of all shapes move into a great void, where they are crowded together and produce a single vortex, where colliding with each other and circulating in all manner of ways, they separate out like to like. When, because of their great number they are no longer capable of moving around in equilibrium, those that are fine spread out into the outside void, as if sifted, while the rest hold together and becoming entangled, they unite their motions and create the first spherical structure. This stands apart like a membrane, containing in itself all kinds of bodies. As they whirl around, due to the resistance of the middle, the surrounding membrane becomes thin, and the close packed atoms flow together due to touching the vortex. In this way the earth came into being, the atoms which had been borne in to the middle remaining there together. Again the surrounding membrane itself is increased, due to the influx of external bodies.⁵ As it moves around in the vortex, it takes in whatever it touches. Some of the bodies which become entangled form a structure which is firstly moist and muddy, but which dries out as it revolves with the vortex of the whole, and then ignites to produce the constitution of the stars.⁶

⁴ As we shall see, although Leucippus and Democritus deny an initial state (in itself an interesting move relative to this paradox) they still face some of the problems of this paradox.

⁵ Reading *epekruisin* here with the MSS tradition (the alternative being *epekkrisin*, see G. S. Kirk, J. E. Raven, M. Schofield *The Presocratic Philosophers*, 2nd edition, 1983, Cambridge: Cambridge University Press (KRS)). I disagree with KRS's 'attraction' here on two counts – there are no attractive forces for Leucippus and Democritus, only contact actions, and the vortex takes in whatever it touches (so there is no need to suppose attraction).

⁶ Diogenes Laertius IX, 31.

So atoms move around in the void and somehow from a vortex, where their separating out ‘like to like’ generates a cosmos. This happens at many places and times in the infinite void. Which times and places, and why, will be an important question for this paper.

II

We do have some further information on the like to like principle. Sextus Empiricus tells us that:

There is an old view which, as I said previously, has long been prevalent among the *phusikoi*, that like recognises like. Democritus confirmed of this opinion and Plato spoke of it in his *Timaeus*. Democritus founds his argument on both animate and inanimate things. For animals, he says, flock with animals of the same kind – doves with doves, cranes with cranes, and so with the other irrational animals. Similarly in the case of inanimate things, as can be seen from seeds that are being winnowed and from pebbles on the sea-shore. For in the one case the whirl of the sieve separately arranges lentils with lentils, barley with barley, wheat with wheat; and in the other case, by the motion of the waves, oval pebbles are pushed into the same place as oval pebbles, and round pebbles as round as pebbles, as though the similarity in things has some sort of ability for leading things together.⁷

The word I have translated here as ‘whirl’ is from the same root as the word that is translated as ‘vortex’ in the previous passage. It is very important in translating the final sentence not to use the word ‘force’. There is no equivalent for it in the Greek here. ‘Force’ can also be misleading here in suggesting that there is always some form of attraction working at a distance between similar things. This is not so. In order for the like to like effect to come into play, there must be motion. There is no suggestion here that if we leave a mixture of lentils, barley and wheat in a sieve,⁸ that they will separate out without the sieve being whirled, or that similar stones on the beach will separate out if they are not agitated by the waves.⁹ So it may be better to think of like to like as a principle,

⁷ Democritus Fr. 164, Sextus Empiricus *Against the Mathematicians* VII 116–118.

⁸ Theories of gravitation based on vortices (e.g. Descartes) were based on vortex action (the observed effect being that a whirlpool will drag objects into its centre), and such theories survived into the eighteenth century, until a determination of the shape of the earth confirmed Newtonian ideas (Newton’s theory of gravity predicted an earth slightly bulged at the equator and flattened at the poles, the Cartesian theory vice versa). See Descartes, *Principia Philosophia*, 1644, Newton, *Philosophiæ Naturalis Principia Mathematica*, 1687.

⁹ Cf. Pseudo-Plutarch IV/19, (the quote is from Homer, *Odyssey* XVII/218): “Democritus says that air is broken into similarly shaped bodies and these are rolled in with pieces of the voice.

or an effect of motion, rather than a force in itself.¹⁰ This is important, for if you think of like to like as a universal attractive force then you are committed to believing that like to like operates outside of vortices. If it is an effect dependent on a specific type of motion, then it may not operate outside of the vortices. Is a specific motion required or will chaotic motion suffice for like to like to come into play?¹¹

Plato's *Timaeus* is an interesting parallel here. Plato too advocates a like to like principle, but requires specific types of motion for this to work.¹² In the pre-cosmic chaos, it is the fact that the receptacle shakes like a winnowing basket that produces a separation of like to like, not just the general chaotic motion. At *Timaeus* 57c and 88de we are told that this shaking continues in the cosmos. At *Timaeus* 58a ff. we are told of the compressive effect which the rotation of the cosmos has on the elements, making them intermingle. Like to like here is dependent on specific types of motion. There is no universal attraction of like to like, nor is there any force which operates at a distance. Similarly at *Timaeus* 80bc electricity and magnetism are explained as due to contact action and mutual replacement, and there is an outright denial that any attraction is involved.¹³

III

On the issue of forces in Democritus, Taylor says there is:

Some evidence that Democritus' dynamics postulated three fundamental forces, a repulsive force which plays the role of impact in conventional corpuscular theory and two

For jackdaws sit with jackdaws and: "God always leads like with like" On the seashore we see pebbles like to each other in the same place, the round ones and the long ones. So too with sieves, where things of like form are brought together, but beans and chick-peas are separated." Pseudo-Plutarch is wrong here to think the sorting is by form – actually it is by density.

10 A modern parallel here – why do larger breakfast cereal flakes come at the top of the packet and smaller ones at the bottom? If the packet has been transported upright, agitation in transit means the smaller but not the larger flakes can drop through the gaps between flakes. No one would suggest that there is a like to like attractive force between same sized breakfast cereal flakes!

11 This sieving does work and was agricultural practice. The contents of the sieve are separated out by density.

12 Plato is critical of cosmogony based on this alone, as for him the cosmos is a harmonious blend of opposites, something highly unlikely to be produced from a like to like principle alone, see *Laws* 889b.

13 Attraction, *holkê*, *Timaeus* 80c3.

kinds of attractive force, one which draws together atoms of the same shape and another which holds together atoms of a different shape in an atomic aggregate.¹⁴

Taylor's motivation here is Philoponus' concern that if atoms did actually come into contact with one another,¹⁵ nothing would separate them and they would coalesce into a single body. This would be a breach of the principle that one thing cannot come to be out of many.¹⁶ Taylor then suggests that the atoms can come close but not collide due to a short range repulsive force. They can also form aggregates without touching in entanglement by means of a short range attractive force. I will examine some objections to this view which undermine the idea of fundamental forces in general in Leucippus and Democritus.

There are several reasons to be suspicious of Taylor's theory. Firstly, there is an ontological issue. The early atomist's ontology is generally taken to be atoms and the void. There is no mention of any forces beyond the existence of atoms and the void. Indeed, it may be that postulating forces for the early atomists runs contrary to a key fragment:

By convention sweet, by convention bitter, by convention hot, by convention cold, by convention cold, but in reality atoms and the void.¹⁷

If that sets out a general programme of reduction, rather than merely the reduction of perceptual qualities, then non-reductive forces look odd.¹⁸ If we construe like to like as an effect of atoms in motion rather than as a force there is no problem.¹⁹ There is much further doxographical evidence that the early atomist

¹⁴ Taylor (1999) p. 194.

¹⁵ Philoponus *Commentary on Aristotle's Physics* 494, 198ff, *Commentary on Aristotle's On Generation and Corruption* 158, 26ff. and 160, 7ff.

¹⁶ Taylor (1999) pp. 186–187.

¹⁷ Democritus Fr. 9.

¹⁸ It is also significant that Democritus takes a reductive line on mind/soul, believing it to be constituted from spherical atoms – see Aristotle *de Anima* 403b30.

¹⁹ There is a seventeenth century parallel to our discussion here. Descartes held that there were no forces which acted at a distance, either attractive or repulsive and that corpuscles acted on each other by contact action only. Gravity was an effect of vortices and not a fundamental, universal force. The corpuscles had dimensions and motion but no other properties and all perceptual qualities were reducible to the interactions of the corpuscles. Newton on the other hand held that gravity acted at a distance, but was notoriously coy on the nature of gravity, replying 'hypotheses non fingo' (I make no hypotheses) when asked. Historically, the matter was settled empirically. Descartes' and Newton's theories led to different predictions for the shape of the earth. Both predicted an oblate spheroid, Newton's bulged at the equator and narrower at the poles, Descartes vice versa. Expeditions to measure the actual curvature of the earth in the middle of the eighteenth century came down decisively on Newton's side. Newton was accused for re-introducing scholastic qualities (his gravity could not be reduced to the

ontology was atoms and the void, or atoms, void and motion and none that suggest an independent existence for forces.²⁰ There is also related evidence that the atoms were considered to be characterless. Stobaeus tells us that:

Democritus says that nothing is coloured in nature, as the elements are characterless (*apoiā*),²¹ both the solid and the empty.²²

Secondly, Aristotle juxtaposes the one into many and the many into one issue with a strong statement about the entangling of atoms. He does not perceive a problem of many atoms becoming one entity if they entangle. He says that:

Leucippus and Democritus say that the one does not come from many nor the many from one but that all things are generated by entangling (*sumplokē*) and scattering.²³

The verb Aristotle uses here, *sumplekein* has a primary meaning of to twine or plait together or to entangle and is also used of wrestlers when they become locked together, so there is no question of Aristotle's meaning here. Simplicius quotes Aristotle's lost *On Democritus* to make the same point,²⁴ and in his commentary on Aristotle's *On the Heavens* has the intertwining of atoms due to their shape some being hooked, some convex, some concave, etc.²⁵

Thirdly, let us suppose for a moment that there is a short range attractive force and a short range repulsive force as Taylor suggests. In order to get the atoms to group together but not touch, there must be a balance between those forces. If the attractive force is too strong relative to the repulsive force, we get touching, too weak and the atoms do not group together. Either alternative is a conceptual possibility and both lead to uninhabitable universes. If the attractive force is too strong there will eventually be a Parmenidean unity with all the atoms coalescing together,²⁶ too weak and there will be no atomic groupings

dimensions and motions of particles as other qualities had been by Descartes) and re-introducing occult qualities (his gravity could not be explained in terms of the motions and collisions of particles but required something else unexplained, unlike Descartes). See Descartes, *Principia Philosophia*, 1644, Newton, *Philosophiæ Naturalis Principia Mathematica*, 1687, on the curvature of the earth experiment, see T. L. Hankins, *Science and the Enlightenment*, Cambridge University Press, Cambridge 1985, Ch. III.

²⁰ See e.g. Aristotle *Metaphysics* I/4 985b4 ff., *Generation and Corruption* I/8 325a2 ff., Simplicius *De Caelo Commentary* 242, 18 ff.

²¹ LSJ give 'without quality or attribute' for *apoiōs*.

²² Stobaeus I, 16, 1.

²³ Aristotle *On the Heavens* III/4, 303a7.

²⁴ Simplicius, *De Caelo Commentary*, 295, 11.

²⁵ Simplicius, *De Caelo Commentary*, 242, 21.

²⁶ Again if there is no origin for the universe unlimited time will have elapsed and this will have already occurred.

such as the earth or human beings. Why though would there be this balance? Since everything we know about Democritus indicates that he rejects providence and design, that cannot be the reason, however providential this supposed arrangement may look. How did the early atomists treat the properties of the atoms? Simplicius reports Leucippus as saying that there were an infinite number of shapes and sizes for atoms:

Leucippus supposed there to be an infinite number of atoms that are always in motion and have an infinite number of shapes on the grounds that nothing is such rather than such (*dia to mēden mallon toiouton ê toiouton einai*).²⁷

Simplicius' wording here suggests that *ou mallon* (not rather than) is a general principle for what is rather than something which applies only to the shapes and sizes of atoms. Translated literally, *ou mallon* means 'not rather' as in a sentence such as 'not x rather than y'. This does not mean a preference for y though. It rather asserts an indifference, or lack of preference between x and y.²⁸ The following passage from Plutarch on Democritus would seem to confirm that *ou mallon* is used quite generally by him:

He said that thing exists no more (*mê mallon*) than nothing 'thing' being the name of body and 'nothing' of void, the latter having a nature and substance of its own.²⁹

Here I follow Barnes' paraphrase that 'There is no more reason for there to be occupied than for there to be unoccupied areas of space.'³⁰

If we treat the supposed short range forces in a similar, *ou mallon* manner with respect to the magnitude of the forces we get a mess. There will be atoms with strong attractive forces which will coalesce and atoms with strong repulsive forces which will never form aggregates, which we have neither theoretical nor doxographical reason to suppose. Any attempt to say there is a universal magnitude to the supposed short range forces runs into two difficulties. Firstly, why, if there are universal magnitudes for these forces are there not a universal size and a universal shape for atoms? Secondly, if these forces have universal

²⁷ Simplicius *Physics* 28, 8. Cf. Simplicius *Physics* 28, 24, Simplicius *De Caelo* 295, 7, Aristotle *Physics* 203a21, Aristotle *On Generation and Corruption* 314a22.

²⁸ Cf. J. Barnes *The Presocratic Philosophers*, second edition, Routledge and Kegan Paul, London 1982 pp. 553 ff.

²⁹ Plutarch, *Adversus Colotem* 1109a. Cf. Aristotle *Metaphysics* 985b4, Simplicius *Physics*, 28, 11–12.

³⁰ Barnes (1982) p. 405.

values, why do they have those specific values?³¹ What sufficient reason is there for these values rather than any other values?³²

A fourth reason to be suspicious of Taylor's theory is that there is plenty of explicit doxographical evidence that the atoms do indeed collide with one another. A good example here is Alexander who says that:

Leucippus and Democritus say that the atoms move by mutual blows (*allêlotupousas*) and striking (*krouomenas*) against each other.³³

The primary meaning of *krouein* is to strike against or strike together, while the *tup* root in *allêlotupousas* indicates a blow, so there is no mistaking the meaning here.³⁴ Seneca *Natural Questions* V. 2 gives Democritus' account of wind. He reports Democritus as saying that in an empty square or street people can pass unhindered, but when there are many people they bump into each other and become entangled with one another and flow together. Similarly with atoms, where the flowing together constitutes wind. Seneca uses a lot of percussive verbs for the contacts without any sense at all that people might come close and then recoil rather than actually bump into each other and become physically entangled.

That Philoponus was concerned about what he thought the unfortunate consequences would be should atoms collide does not mean that Leucippus and Democritus shared his concerns. There is no evidence they did and Aristotle, who wrote a lost work *On Democritus* does not seem to have been bothered by these concerns either. Given Aristotle's critical attitude that is very surprising if there is a problem here. As Bodnar has argued, in the absence of any other source for such a critical idea, it is best to see Philoponus inferring what the atomists might have said to resolve this supposed difficulty rather than reporting what they actually said.³⁵ There is also significant evidence that the early atomists considered their atoms to be solid.³⁶ The word used is *nastos*, for

31 One might be concerned about whether Democritus would think of quantification of these supposed forces in a modern manner, but they must have some determinate value (whether we could know that or not) and the attractive and repulsive forces must have some determinate relationship to one another.

32 This is problematic for Taylor who attributes a strong belief in sufficient reason to the early atomists, see Taylor (1999) p. 189.

33 Alexander, *Commentary on Aristotle's Metaphysics*, 36, 21.

34 Cf. Aetius I, 12, 6, Philo *On the Eternity of the World* 2, 489.

35 I. M. Bodnar, 'Atomic Independence and Indivisibility,' *Oxford Studies in Ancient Philosophy* 16, 1998, 35–61.

36 Aristotle Fr. 208, Stobaeus I, 10, 14, and I, 14, 1 and I, 16, 1, Simplicius *De Caelo Commentary* 295, 5, Philo Judaeus *De Plantatione* 7, 3 all use *nastos*.

which LSJ give ‘close pressed, firm’ and ‘solid’. If so, they may have simply taken the view that when atoms collide they rebound. It is best then to retain the orthodox view that atoms can collide and entangle, when we do not have to postulate short range forces, either attractive or repulsive. There is then no general notion or theory of force at a distance in the early atomists that like to like could be a part of.

On the related issue of weight, I take the view that weight is not an intrinsic property of the atoms for Leucippus and Democritus but that atoms only have weight in vortices. There are two key passages here. Pseudo-Plutarch, discussing the primary properties of atoms, says that:

Democritus said there were two, size and shape, while Epicurus supposed there to be a third, weight.³⁷

Stobaeus also tells us that:

Democritus said of the primary bodies (they being the solids) that they do not have weight and are moved by mutual blows in the unlimited.³⁸

Of course Democritus has an account of weight as we recognise it in the cosmos and these two passages should be taken as referring to the intrinsic properties of atoms and what happens outside of the vortices. Where passages seem to implicate weight in the behaviour of atoms in the void,³⁹ these can be disarmed by the application of what in modern terms would be the distinction between weight and mass.⁴⁰ For the atomists what we would call mass is simply a function of atomic size, as what constitutes the atoms does not come in different densities. In reply to the concern that a vortex will only sort according to weight with respect to its axis of spin, and not to a central point as required (where the earth might be assumed to be),⁴¹ there are two replies. One is that this is not actually true of the vortices,⁴² the second is that the real key here is not the actual dynamics of vortices but what the early atomists may well have believed about them and that is that vortices will indeed generate the phenomena required of them to explain weight.⁴³

³⁷ Pseudo-Plutarch, I, 13, 8.

³⁸ Stobaeus I, 14, 1.

³⁹ Simplicius, *Physics Commentary*, 1318.33ff.

⁴⁰ Cf. D. O'Brien (1981), *Theories of Weight in the Ancient World*, vol. 1 *Democritus*. Paris and Leiden. p. 40 ff.

⁴¹ D. J. Furley (1989) *Cosmic Problems*, Cambridge: Cambridge University Press, Ch. 7 & 8.

⁴² D. Konstan (1979), 'Problems in Epicurean Physics,' *Isis* 70, 1979, 394–418.

⁴³ Cf. Taylor (1999) p. 184.

IV

If the like to like principle does operate outside of the vortices, then there is a serious theoretical problem. As there is no beginning to the universe for Leucippus and Democritus an infinite amount of time has already occurred.⁴⁴ During that time, everything should have sorted out like to like but it has not.⁴⁵ We do not have the end state of the complete association of like things. Nor is there any sense that we are closer to that state than in the past or that we are progressing towards that state. Vortices will form, cosmoi will be generated, eventually they will be destroyed again in what looks like an endless cycle.⁴⁶

One reasonable objection to this line of thinking is that it is too modern and unlikely to have occurred to any ancient thinker. The classic modern example here is an argument based on thermodynamics that the universe must have a determinate age. According to the second law of thermodynamics, the entropy of any closed system always increases. The universe is by definition a closed system, its entropy always increases but as we are not yet in the state of maximum entropy, an infinite amount of time cannot yet have elapsed. More loosely, heat always flows from high temperatures to low temperatures so there is a tendency towards a thermal equilibrium (a complete equality of temperature). We have not reached this state of the heat death of the universe yet, so an infinite amount of time cannot have elapsed.

However, there are parallels for this sort of argument in ancient thinking we can look to, in Aristotle, Plato and Empedocles. In *On Generation and Corruption*, Aristotle conducts a thought experiment in relation to criticism of his theory of natural motion. He says that:

The problem some see arising here is now solved, that is how each of the bodies (i.e. earth, water, air, fire) travelling to their own places have not, in an unlimited amount of time, become separated from the other bodies. The reason for this is that they change into each other. If each had remained in its own place without change they would have separated long ago. They are though changed due to the double motion and because they are changed none is able to remain in any ordered place.⁴⁷

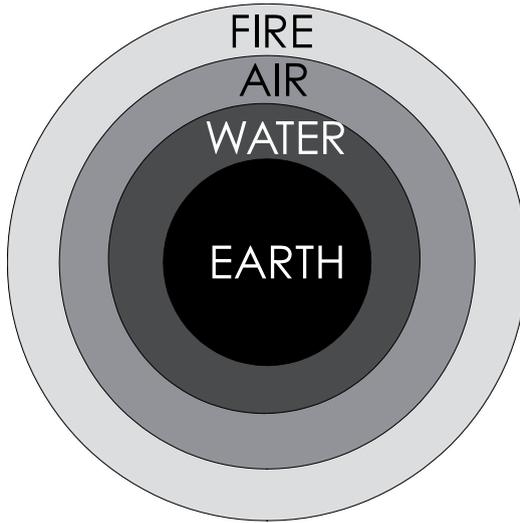
⁴⁴ On the eternity of the universe for Leucippus and Democritus, see Aristotle *On the Heavens* 300b8, Cicero *De Finibus* I, 6, 17, Pseudo-Plutarch *Miscellanies* 7.

⁴⁵ An alternative is that everything has become a tangled mess, with all the atoms inextricably linked together.

⁴⁶ See Hippolytus *Refutation of all Heresies*, I, 13, 2.

⁴⁷ Aristotle, *On Generation and Corruption* 337a8–16.

The natural motions of earth and water towards the centre of the cosmos and air and fire away from it would separate out with earth in the centre and the other elements in concentric shells, like this:



As Aristotle believed that there was no beginning to the cosmos, there had been ample time for this to have already occurred. It had not, therefore there was something which opposed this tendency. This is the motion of the sun (referred to here as the double motion, its daily motion producing day and night and the annual motion producing the sequence of the seasons) which affects the terrestrial realm and agitates the elements.⁴⁸

In Plato's *Timaeus* the pre-cosmos chaos the receptacle is filled with powers that are not balanced or evenly distributed, so it is itself shaken by these things and by this motion shakes them in turn.⁴⁹ It thus acts like a winnowing basket,⁵⁰ and just as the process of winnowing sorts the corn from the chaff, so the four elements are separated out, the most unlike furthest away and the most like closest together. *Timaeus* 53a is quite specific that it is the four kinds that are sorted:

⁴⁸ See Aristotle, *On Generation and Corruption* 337a8ff., cf. Aristotle, *Meteorology* I/2.

⁴⁹ Plato, *Timaeus* 52d.

⁵⁰ A *plokanon* is anything woven, a *liknon* is specifically a winnowing-basket. See here Cornford (1937) p. 201 for discussion and a (marvellous!) illustration.

In the same way at that time the four kinds were shaken by the recipient, whose motion was like that of an instrument for shaking, and separated the most unlike kinds furthest from each other and forced together the most like kinds, so that the different kinds had different regions, even before the universe was organised out of them.⁵¹

However, if this winnowing effect does take place, there seems to be no limit on it so eventually we would reach a situation where the four elements are separated out.⁵²

Exactly how this fits into Plato's picture of pre-cosmic chaos and his cosmogony in general need not concern us here. What is important is that Plato conducts the thought experiment of what will happen if like to like is allowed to apply in an extended and uncontrolled manner. Indeed the use of the agricultural metaphor of winnowing suggests a criticism of Leucippus and Democritus here, on the grounds that winnowing corn does not produce any interesting order, but merely the separation and congregation of the entities involved.⁵³

It is also important to mention Empedocles here as he too envisages the possibility of the complete separation of the elements over time but contrary to Plato and Aristotle, he embraces that possibility. The ascendancy of love will lead to a complete association of the elements of earth, water air and fire while the subsequent ascendancy of strife will lead to the complete dissociation of the elements.⁵⁴

In the previous section, I argued that there was a problem with the magnitudes of Taylor's supposed short range forces. If we treat like to like as a universal force, there is a similar difficulty. What is the magnitude of the like to like force? If we treat the magnitude of like to like as with the shapes and sizes of atoms as *ou mallon*, then we get the bizarre situation of each atom having a different value. That will be very problematic for Taylor's view, as atoms that have very high values might well be subject to coalescing, if their attraction

51 Plato, *Timaeus* 53a.

52 Especially if there is no limit to the amount of duration prior to the formation of the cosmos.

53 *Laws* 889b is critical to Plato's cosmogony and his criticism of his predecessors: "Let me put it more clearly. Fire, water, earth and air all exist due to nature and chance they say, and none to skill, and the bodies which come after these, earth, sun, moon and stars, came into being because of these entirely soulless entities. Each being moved by chance, according to the power each has, they somehow fell together in a fitting and harmonious manner, hot with cold or dry with moist or hard with soft, all of the forced blendings happening by the mixing of opposites according to chance. In this way and by these means the heavens and all that pertains to them have come into being and all of the animals and plants, all of the seasons having been created from these things, not by intelligence, they say, nor by some god nor some skill, but as we say, through nature and chance." A 'fitting and harmonious' ordering will not be generated by like to like principles, as that ordering has a mixture of types, and indeed, as Plato emphasises here, of opposites.

54 See Empedocles Fr. 117.

overpowered the supposed short range repulsive force. Even without an interpretation involving short range attractive or repulsive forces, variation in the magnitude of like to like will cause problems in cosmos formation in the vortices and may well cause clumping of high value atoms outside the vortices, for which we have no evidence. Any attempt to suppose a universal value will once more run into the two problems of why is there not a universal shape and a universal size for atoms, and what sufficient reason determines that we get this value for like to like rather than any other value. If we consider like to like to be an effect that is generated by certain types of motion, then the problems associated with the atoms having an intrinsic like to like property vanish. Variations in how much like to like separation we get can be put down to the differing distributions of the size, shape and motion of the atoms.

Outside of the vortices clearly one will not get the whirling motion required for like to like separation as with the analogy of the sieve being whirled to separate out lentils, barley and wheat. There is a second analogy in the Sextus passage though and that is of pebbles on the beach undergoing a sorting effect due to the motion of the sea. One might say that the sea is in random motion, so too are the atoms in the void, so we might expect the like to like effect outside of the vortices. Certainly that is an important consideration, but I would suggest the following dissimilarity between the motion of the sea and atoms in the void. The motion of the sea, as it affects pebbles on the beach, might be considered to be cyclical rather than random. It is repetitive waves which supposedly sort the pebbles, not a general random motion of the sea and there is no suggestion that there are repetitive waves of atoms in the void. In the Sextus passage it is notable that it is the motion of the waves which produces the sorting effect, not the motion of the sea in general.

V

There is no direct evidence that like to like works outside of vortices for Leucippus and Democritus. There is quite a lot of indirect evidence, some not often attested, that it does not. Pseudo-Plutarch tells us that, for the early atomists:

The cosmos as it is now was formed in a curved manner in this way.⁵⁵ The atomic bodies were in an unprovidential, chance, continuous and extremely rapid motion at the same time, and many of these bodies gathered together, having a variety of shapes and sizes.⁵⁶

⁵⁵ The verb here, *perikeklasmenein* has a primary meaning of to twist or bend.

⁵⁶ Pseudo-Plutarch, I/4.

While Pseudo-Plutarch gives us four descriptions of motion prior to cosmos formation (unprovidential, chance, continuous and extremely rapid), there is no mention of the like to like principle. On the contrary, it is a variety of shapes and sizes which come together to generate a cosmos. Pseudo-Plutarch points here to a very strong theoretical reason why vortices cannot be formed by the like to like principle. Vortices have to contain the great variety of shapes and sizes of atoms which will eventually constitute cosmoi. It is the vortices job to do the like to like sorting, not that of the motion in the void. There must be a coming together of many unlike atoms for vortex formation. In the Diogenes Laertius passage on early atomist cosmogony above, vortices are formed by ‘cutting off from the infinite many bodies of all shapes move into a great void’. There is no mention of like to like until the vortex forms, and again the vortex is formed of many different shapes of bodies. In relation to this Simplicius tells us that:

When Democritus says that ‘A vortex of all shapes is separated off from the all’ (how or by what cause he does not say), it appears that this occurs spontaneously or by chance.⁵⁷

Simplicius tells us that the atoms outside the vortex for Democritus:

Conflict and are moved in the void by their unlikeness and the other differences we spoke of.⁵⁸

That is interesting because it is their unlikeness, rather than their likeness which is related to their motion. According to Aristotle, Leucippus and Democritus viewed the formation of a vortex as a matter of chance:

There are some who make chance the reason for the heaven and all of the cosmoi. For from chance arose the vortex and the motion which by separation brought the universe into a state of order.⁵⁹

The sequence here is interesting and important. The vortex and the motion by which separation occurs arise by chance, then we get the separation. The separation one presumes happens like to like, but the vortex and the motion required to generate like to like separation do not. Finally, Aristotle has a discus-

⁵⁷ Simplicius *Physics* 327, 24. See also Simplicius *Physics* 327, 330, 14, Themistius *Physics* 49, 13, Cicero *De Natura Deorum* I, 24, 66. Simplicius, *Physics* 330, 14–17 also says that: “It would seem that ‘the ancient theory which denies chance’ refers to Democritus. For although he appears to use chance in the making of cosmoi, when he is more nuanced he denies that chance is the reason for anything.”

⁵⁸ Simplicius *De Caelo* 295, 9–10.

⁵⁹ Aristotle, *Physics* II/4, 196a24 ff.

sion of the motion of atoms outside the vortex for Democritus at Aristotle *De Caelo* 300b8ff. What Aristotle argues here is that there is no natural motion outside the vortex and this in his view is incoherent. If there was like to like motion outside the vortex, Aristotle would recognise that as natural motion, but he does not even mention like to like outside the vortices.⁶⁰

VI

Taylor argues against a role for chance in Leucippus and Democritus on the grounds that:

The recognition of pure chance is, however, inconsistent with the Principle of Sufficient Reason, which we know the atomists accepted.⁶¹

Taylor's prime example of the use of sufficient reason in the early atomists is the passage we looked at earlier from Simplicius which reports Leucippus as saying that there were an infinite number of shapes and sizes for atoms on that no particular size or shape was to be preferred.⁶² Is this a straightforward application of the principle of sufficient reason though? As Mourelatos has argued,⁶³ there must be an upper bound on atomic size, or there may be atoms the size of the universe, and there must, on general atomist principles that there is a smallest size, be a lower bound as well. Where those bounds are set will be arbitrary and one might add that if Democritus did limit the size of atoms to below that of human perception, that too would be an arbitrary bound.⁶⁴ Why do the early atomists take this approach? Parmenides' argument led to the conclusion that what exists is one and is spherical. There is no real question of its

60 Cf. Aristotle, *Parts of Animals* 641b20–24: “It seems that order and definiteness are very much evident in the heavens, rather than in us, where change and chance pertain to that which perishes. There are some who, while accepting that each animal exists and was generated by nature, say that the heavens were put together by chance and spontaneity, in which there does not appear to be any chance or disorder whatever.”

61 Taylor (1999) p. 191.

62 Simplicius *Physics* 28, 8. Cf. Simplicius *Physics* 28, 24, Simplicius *De Caelo* 295, 7, Aristotle *Physics* 203a21, Aristotle *On Generation and Corruption* 314a22.

63 A. P. D. Mourelatos (2005) *Intrinsic and Relational Properties of Atoms in the Democritean Ontology*. In *Metaphysics, Soul and Ethics in Ancient Thought*, ed. R. Salles, Oxford: Clarendon Press, p. 50.

64 “On this Democritus and Epicurus differed, that Epicurus believed that all the atoms are very small, and Democritus believed that some atoms are very large.” Dionysius, *ap. Eusebium Preparatio Evangelica* xiv, 23, 3. See Epicurus *Letter to Herodotus* 56, 1–4 for Epicurus' view.

size, at least in relation to anything else.⁶⁵ If there are to be multiple things though, as Leucippus and Democritus assert, what are their shapes and their sizes? Here the early atomists assert that there are no preferred shapes or sizes, and so with an unlimited number of atoms there are an unlimited number of shapes and sizes.

What I want to suggest in relation to this is that an interesting way to understand the early atomists is to suppose that they treated the distribution of atoms throughout the void as *ou mallon* and consequently treated the times and places of cosmos formation as *ou mallon*, and that as well. Their motivation for doing this I suggest, as with the *ou mallon* attitude to the sizes and shapes of atoms, are some aspects of Parmenides' critique of cosmogony along with a perennial paradox in cosmogony.⁶⁶ Parmenides says that:

It never was nor will be, as it is now, all alike,
one and continuous. What birth will you seek for it?
In what way, from what source did it grow? I will not allow you
to think or say from not being, for it is not to be thought or said
that it is not; that it is not; and what warrant might have driven it
later rather than sooner, beginning from nothing, to grow?⁶⁷

The last part here has been taken as a sufficient reason argument and while it is in the context of change in general, it has also been taken to be about cosmogony and in some ways is the most radical case here. Parmenides may also raise a 'where' question. He also says that:

As there is a furthest limit, it is complete,
from all directions like the bulk of a well-rounded sphere,
equivalent in all ways from the centre. For it must not be any larger
or any smaller here or there.⁶⁸

65 Parmenides Fr. 8.

66 There are issues here concerning how we construct the history of Greek philosophy. I am suspicious of the lineages handed down to us by the doxographers and ultimately of any Hegelian source of thesis/antithesis working itself out through Greek philosophy. Here though I think we do have good reason to believe that Leucippus and Democritus responded to Parmenides, not least in their terminology and in the reactions of Aristotle. Here I want to suggest that in addition to the usual notion that the early atomists asserted the existence of not-being in the sense of the void in order to be able to have a coherent theory of change, that they also had a response in terms of the shapes and sizes of their multiplicity if atoms and in terms of some paradoxes in cosmogony that Parmenides addresses.

67 Parmenides Fr. 8, 5–10.

68 Parmenides, Fr. 8, 42–45.

If this is taken literally and spatially,⁶⁹ as asserting an entirely homogeneous and spherical universe,⁷⁰ then there is a sufficient reason issue about where cosmogony starts in a homogeneous entity as well as when it starts.⁷¹

There is a dilemma in cosmogony which can be expressed like this. If the original state of the universe is homogeneous, and it obeys laws which are place invariant, it is then difficult to see how anything interesting will develop in that universe. If the original state of the universe is not homogeneous, we require some further explanation of why it has this particular state as opposed to any other. Modern big bang cosmogony has this problem. If we assume that what expands from the initial state is entirely homogeneous, and that it expands isotropically, then all that will result will be a larger homogeneous universe, which only differs from earlier stages in being less dense and cooler. The modern solution to this difficulty is to invoke quantum mechanics at an early stage to produce some differentiation in the homogeneity.⁷² Parmenides can be seen as posing problems if we assume homogeneity and sufficient reason.

Leucippus and Democritus have an interesting solution which involves denying that there is an initial state of the universe. They do not specify any particular distribution of atoms at any point in time or any original distribution. There are two possibilities here. The first is that they believe that outside of the vortices there are genuine chance events and so the time and place of cosmos formation is genuinely random.⁷³ A problem here though is that once the vortex

69 I am not here asserting that this passage should be taken literally and spatially, just that it may have been taken that way with the perceived challenge of where cosmogony might start.

70 Interestingly, the sphericity here may call on sufficient reason considerations. Can the sphericity of what is be derived from the nature of what is? The homogeneity can, I believe, on the grounds that what is does not exist, leaving us simply with what is, which cannot be permeated with holes of what is not. The sphericity though does not seem to come from the nature of being itself, but from a further sufficient reason consideration.

71 This may function both as a critique and a challenge – if for example, Anaximander begins with a homogeneous sphere of the unlimited, where does cosmogony begin without breaching sufficient reason?

72 At an early stage of the universe, quantum effects create inhomogeneities in the distribution of matter/energy throughout the universe (the famous ‘ripples’ in space/time). The areas of greater energy density will then act as gravitational attractors, stars or galaxies will then form around these areas of higher energy density. In reply to the question of why here rather than there, the answer will be that quantum mechanics is fundamentally probabilistic in its nature, and can only give probabilities of energy distribution. See J. Silk, *The Big Bang*, Freeman & Co, London, 2001, M. Rowan-Robinson, *Cosmology*, Oxford University Press, Oxford, 2003.

73 Here one might compare the Epicurean swerve. Lucretius, *On the Nature of Things*, II, 216–225: “When bodies fall through the void due to their weight, at quite uncertain times and places they swerve a little from their course, just enough for this to be called a change of motion. If they were not accustomed to swerving, they would all fall down, like drops of rain

forms, cosmos formation seems a necessary consequence with no role for chance in the separating out and distribution of the atoms, and Leucippus and Democritus do not refer to chance in describing the world about us. Why then would there be a change in the behaviour of the supposedly unchanging atoms just because they have formed into a vortex?

The second possibility is that there is a chain of necessity outside the vortex but the distribution of the atoms is *ou mallon*. There is no preferred original distribution and there is no original state. On sufficient reason grounds there is no reason to suppose any distribution of atoms rather than any other. That means that even if we take atomic velocities and collisions to be necessary and deterministic, sites and times of vortex formation will be *ou mallon* as well.

If Leucippus and Democritus did take this view, that there is no initial arrangement of the atoms and no preferred arrangement of the atoms, then they have a coherent, consistent and interesting reply to Parmenides. Where Parmenides poses where and when sufficient reason questions for cosmogony, Leucippus and Democritus reply *ou mallon*, there are no preferred places or times.⁷⁴ Similarly, in relation to sufficient reason problems with the size and shape of atoms they reply *ou mallon*, there are no preferred shapes and sizes. The two uses of *ou mallon* are not identical but are related. For shapes and sizes we get all shapes and sizes of atoms, but we do not get vortices forming at all places and at all times. Perhaps this difference is not so great though in that if the universe does exist for an infinite amount of time, then ultimately all places will be sites for vortex/cosmos formation, though not all at a single moment of time. So too in an infinitely large void with an infinite amount of matter, there will be vortex/cosmos formation at all times, though not in all places at a single time. So Leucippus and Democritus do treat space and time slightly differently from size and shape in respect of *ou mallon* considerations, but perhaps justifiably so.

Does this interpretation fit with the evidence we have on Leucippus and Democritus? Certainly the times and places of vortex/cosmos formation can be seen as *ou mallon*. If there are no preferred places, this would also accord with the evidence of Hippolytus, who says:

The spaces between cosmoi are not equal, in places there are more and in others less.⁷⁵

through the deep void, and there would be neither collisions nor blows between the primary bodies. Thus nature could never have produced anything."

⁷⁴ Assuming here that space and time are homogeneous for Leucippus and Democritus. That is demonstrable for space and a reasonable assumption for time.

⁷⁵ Eusebius *Preparatio Evangelica* XIV, 22, 3. Cf. Metrodorus of Chios, a pupil of Democritus (KRS translation, p. 420 note 5): "It is strange for one ear of corn to be produced in a great

In relation to this, Stobaeus' evidence on Anaximander is interesting:

Anaximander declared the infinite cosmoi to be equally far away from each other.⁷⁶

Anaximander is generally thought to have held the principle of sufficient reason on the basis of his account of the earth's stability, that it does not move because there is no reason for it to do so, it having an equal distance to everything.⁷⁷ That makes an interesting contrast with the *ou mallon* distribution of Leucippus and Democritus.⁷⁸

VII

There is a vexed question of chance and necessity for Leucippus and Democritus. The doxography is rather confused and various commentators attribute chance, or necessity, or chance and necessity to the early atomists. There is a view which defends necessity only, citing the early atomists adherence to the principle of sufficient reason and the following Leucippus fragment:

Nothing happens at random (*matên*)⁷⁹, but everything for a reason and by necessity.⁸⁰

plain, and for one world in the boundless." From a modern perspective, we might be somewhat suspicious of the biological aspects of this analogy, but the point in favour of cosmoi distributed in an *ou mallon* manner is clear enough. Cf. Aristotle, *Physics* III/4, 203b:

"If what exists outside of the heaven is unlimited, then so it would seem is body, and so are *kosmoi*. For why here in the void rather than there?" Cf. Philoponus *Commentary on Aristotle's Physics*, CAG 405, 24–27: "What selection would have made this part of the void full, and not another? So if in some part of the void there is a cosmos, there will be in all parts. As the void is unlimited, cosmoi will be unlimited as well." Epicurus will insist that cosmoi grow from seeds. Epicurus, *Letter to Pythocles*, 89, 6–11: "*Cosmos* formation occurs when the appropriate seeds flow in from one *cosmos* or an intercosmos or from many. Gradually, by additions and joinings and migrations to another place, as may occur, and appropriate irrigations of this matter, a state of completion and permanence is reached, which lasts while the underlying foundations are capable of being added to."

76 Stobaeus I, 22, 3 (= Aetius II, 1, 8).

77 Hippolytus, *Refutation of All Heresies*, I, 6, 1–7.

78 Just to make my own view clear here, I do not believe that Anaximander postulated an infinite number of co-existent worlds (see A. Gregory, *Ancient Greek Cosmogony*, London: Duckworth, 2007, Ch. 2) though some in the doxographical tradition did. Even though I think Stobaeus is wrong to attribute infinite co-existent worlds to Anaximander, it is still interesting that he gives Anaximander the view that they are equally spaced in contrast to the early atomist's view.

79 LSJ give 'at random, without reason' for *matên*.

80 Leucippus, Fr. 2. Cf. Cicero *On Fate*, 10, 23 and 17, 39.

To give this fragment its full context, this is what Stobaeus actually tells us:

Democritus says everything happens by necessity. This is the same as fate, justice, providence and cosmos making. Leucippus says that everything happens by necessity, which is the same as fate. He says in his *On Mind*, 'Nothing happens at random, but everything for a reason and by necessity.'⁸¹

One reason why the context is important here is that we might try to split the views of Leucippus and Democritus on this issue, but it seems that Democritus believes that everything happens by necessity as well. However, we have seen that Leucippus and Democritus rethink sufficient reason and there is a great deal of doxography which attributes chance to them.

I want to make two suggestions here. Firstly, it is the *ou mallon* distribution of atoms in the void that gives rise to the idea among the doxographers that there are chance events in Leucippus and Democritus. To be precise about this, the distribution of atoms is *ou mallon*, the atoms themselves behave in a deterministic manner and the times and places of vortex/cosmos formation are *ou mallon*. I am not attributing a theory involving chance to Leucippus and Democritus, merely this *ou mallon* consideration. It is easy to see though how the doxographers could have interpreted this as a theory involving chance.⁸² Whether an *ou mallon* distribution followed by deterministic motion and collisions gives rise to chance or necessary events is an interesting issue and one can see how that might well have generated different opinions among the doxographers.

Secondly, there may be a different situation inside a vortex once a vortex is formed and the like to like principle initiates cosmos formation. The distinction here is that outside the vortex, the distribution of the atoms does matter for what will subsequently occur. However, once the atoms are in a vortex and like to like begins to operate, the distribution of atoms within the vortex may not matter for subsequent cosmos formation.⁸³ Once a vortex is formed it may not matter which parts of the vortex the atoms are in if the like to like principle eventually sorts them together. The explanation of variations between *cosmoi* would be down to the size, shape and number of atoms forming the vortex, not their distribution in the vortex. To be precise again, an *ou mallon* distribution of atoms leads to an *ou mallon* distribution of times and places for vortex formation. There would then be a sense in which events prior to vortex formation

81 Stobaeus I, 4.

82 Aristotle's view that chance events occur in the absence of teleology (even when there is necessity) and its influence would be another factor here.

83 A comparison here would be with a modern centrifuge. The initial distribution of what is in the fluid in the centrifuge tube does not matter, the result in terms of separation is always the same.

could be said to be chance, and events within a cosmos subsequent to vortex formation to be necessary. This is one reason why it is important to be entirely clear when and where the like to like principle operates. If it operates only in vortices, then we get this interesting contrast.

What we get in the doxography then depends on what the doxographers think about the nature of chance and necessity. Certainly there are those who emphasise the role of chance and they are usually hostile to Leucippus and Democritus. Themistius says that:

“They give the greatest role to chance, but have not given to men the slightest account of it – unlimited worlds, the vortex and the controlling order they give no other reason for, but only grasp at chance and the spontaneous.”⁸⁴

Eusebius tells us that:⁸⁵

Those who name as atoms an innumerable multitude of extremely small bodies and suppose empty space unlimited in magnitude say that the atoms move by chance and spontaneity (*automatos*) in the void, clashing together in a disorderly rush they become joined together due to their many shapes and lay hold of each other, and this is the cosmos and what is in it, or rather an unlimited number of cosmosi.⁸⁶

If necessity only applies once a vortex is formed for Leucippus and Democritus, this would accord with the evidence of Diogenes Laertius, who says that for Democritus:

“Everything occurs by necessity, the vortex being the cause for the coming into being of all things, and this he calls necessity”⁸⁷

We have to read the first ‘everything’ here in a slightly restricted way as meaning everything in the cosmos (or perhaps everything in any cosmos) rather than everything in the universe. That though seems justified by the second clause, where the vortex is the cause for everything coming to be. It is no part of Leucippus and Democritus’ scheme that vortices cause further vortices, so the formation vortices themselves are not part of everything here. Necessity is then restricted to what occurs in the vortex. Let us now return to the context of the Leucippus fragment that everything happens by reason and necessity. Stobaeus leads into this by saying that:

⁸⁴ Themistius, *Commentary on Aristotle’s Physics*, 49, 13–16.

⁸⁵ Eusebius *Preparatio Evangelica* XIV, 22, 3. See also Furley (1989) pp. 77 ff.

⁸⁶ Eusebius, *Preparatio Evangelica* XIV, 23, 2–3.

⁸⁷ Diogenes Laertius, IX, 45.

Democritus says everything happens by necessity. This is the same as fate, justice, providence and cosmos making (*kosmopoion*).⁸⁸

If we take the ‘cosmos making’ to be the vortex (what else would it be for Democritus?) then we have something very similar to Diogenes Laertius’ report, that Democritus associates necessity with the vortex. If so we should read ‘everything happens by necessity’ in the Stobaeus report as again everything in the cosmos (or perhaps everything in any cosmos) happens by necessity rather than everything in the universe. That though might lead us to read Leucippus’ ‘everything happens for a reason and by necessity’ in a similar manner.

Aristotle will call an event a chance event in the absence of teleology, rather than the absence of necessity.⁸⁹ So Aristotle may well attribute chance events to Leucippus and Democritus because those events have no teleological purpose, and the doxographical tradition then follows him. Interestingly, in *Physics* II 4, Aristotle contrasts the chance formation of the vortex for the early atomists with the supposed subsequent formation of animals and plants for them, which he says happens ‘by nature’ and not by chance.⁹⁰ While he is being critical here, it does point to an interest difference between what happens outside the vortices and what happens in a cosmos. Simplicius backs Aristotle on this point, and says that the ‘ancient theory which denies chance’ refers to Democritus, who made use of chance when explaining the formation of cosmoi, but then says that Democritus did not use chance to explain anything subsequent to cosmos formation, always citing normal causes.⁹¹

In section IV above we looked at an assortment of passages which show that like to like does not operate prior to vortex formation, many of which asserted that there were chance events prior to vortex formation. As long as we understand chance to mean either the absence of teleology or the consequences of an *ou mallon* distribution of the atoms, rather than the atoms behaving in an uncaused or random manner those passages accord with his interpretation. Pseudo-Plutarch I/26 tells us that:

On the nature of necessity, Democritus says it is the resistance, motion and blows of matter.⁹²

If we understand necessity in this manner, essentially as the necessary behaviour of atoms, then there is necessity both prior to and subsequent to vortex formation. However, if necessity is understood in terms of events, then events

⁸⁸ Stobaeus I, 4.

⁸⁹ KRS (1983) pp. 419–420.

⁹⁰ Aristotle, *Physics* II/4, 196a25ff., cf. *Parts of Animals* 641b20ff.

⁹¹ Simplicius, *Physics Commentary* 330, 14–20.

⁹² Pseudo-Plutarch I/26

are necessary within cosmoi after vortex formation but not in the void due to the *ou mallon* distribution of atoms.

VIII

There is a very good theoretical reason why the like to like principle should not operate outside of the vortices for Leucippus and Democritus. Over unlimited time it would separate everything like to like but this has not yet happened. This sort of consideration was in the minds of Democritus' contemporaries. There is a very good physical reason why the like to like principle does not operate outside of the vortices. It is an effect of a certain type of motion, not a universal force, but a principle based on an agricultural analogy of separating different types of seed using a whirling motion. Without the whirling, there is no separation. There is no textual evidence to support the like to like principle operating outside of the vortices. There is a very good metaphysical reason why like to like or any attractive or repulsive force is not an intrinsic property of atoms. Leucippus and Democritus take an *ou mallon* attitude to the sizes and shapes of atoms and that is an interesting reaction to the application of sufficient reason in Parmenides. The doxography indicates that other than describing the atoms as *nastos* to distinguish them from the void, the atoms are characterless.

There is no initial distribution of atoms in Leucippus and Democritus and the distribution of atoms in the void is *ou mallon*. This means that, even with the regular behaviour of atoms, places and times of vortex formation will be *ou mallon* too. Along with their attitude to the sizes and shapes of atoms, this provides an interesting, consistent and coherent response to Parmenides on multiplicity, change and cosmos formation. There may be an interesting change once vortex formation begins, if the *ou mallon* distribution of the atoms matters for subsequent events in the void but does not matter in the vortex. Where events in the void can reasonably be said to come about by chance in the vortex they are necessary.

It is important that we understand like to like properly in Leucippus and Democritus. It is not a modern attractive force and it is not an intrinsic property of the atoms. It is also important that we understand how and why Leucippus and Democritus use *ou mallon* considerations. This allows interesting possibilities for how we understand Leucippus and Democritus in relation to Parmenides, and how we understand the attributions of chance and necessity to them.