Aristotle, Eleaticism, and Zeno's Grains of Millet*

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Aristotle and the Problem of Movement

Both Parmenides and Zeno are quoted by Aristotle in his works several times; as is well-known, he is usually very hostile to them, and his critiques are mainly addressed against Eleatic monism, i.e., the view that "the all is one." If so, Aristotle claims, plurality, such as we perceive it in the natural world, is not possible and hence change is not possible, either. But if change is not possible, nature cannot be accounted for: as Aristotle argues, nature as well as natural entities are defined by reference to motion. Nature is a principle or cause of being moved and of being at rest in that to which it belongs primarily, and natural entities are those that have within themselves a principle of motion and of rest (*Ph.* II.1, 192b13–14; b20–22). It is arguable that if Zeno's paradoxes against motion are sound, Aristotle's thesis that motion is something inherent to nature might be threatened and, what is more serious, the physical world could not be explained. To be sure, Aristo-

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tle takes as a 'basic assumption' (ἡμῖν δ' ὑποκείσθω) that some or all natural things are changing (κινούμενα – *Ph.* 185a12–13; see also *Ph.* 200b12–15; *Metaph.* 1025b20).

The problem that the all is one dates back to Plato's *Parmenides* (*Prm.* 128a–d), where Zeno, within the dramatic framework of the dialogue, claims that if things are multiple, it must follow that the same things are both like and unlike, which is impossible. Thus, if it is impossible for unlike things to be like, and like things to be unlike, it is also impossible for either of them to be many (in fact, if they were many, those impossibilities could not be avoided; *Prm.* 127e). In the dialogue Zeno contends ("against what is generally argued" – *Prm.* 127e9–10: παρὰ πάντα τὰ λεγόμενα) that there is no multiplicity. It is Plato himself who highlights that Zeno wants to be associated with Parmenides not only in friendship, but also by his writings. Indeed, Zeno's arguments lead to the Parmenidean conclusion: there is no multiplicity, i.e. "the all is one", the tenet that Aristotle ascribes to Parmenides everywhere in order to show that being should not be understood in an absolute sense.[1] While Parmenides suggests that "the all is one",[2] Zeno says "it is not many", but both of them say the same thing insofar as Zeno's argument leads to the Parmenidean view that there is no plurality (or this is the way both Plato and Aristotle appear to have interpreted the issue). If this is so, one might speculate that Zeno imagined his paradoxes in order to support Parmenides' view (although, as is well-known, this is highly controversial);[3] but if Parmenides is right, the natural world, which in Aristotle's view is a world of change, cannot be explained.[4] On the other hand, Aristotle famously argues that some people hold that it is not the case that some things are changing, while others are not. What they want to posit is that, even though everything is changing *all the time*,[5] this goes unnoticed by our sense perception (*Ph.* 253b9–11). Aristotle takes the view that *everything* is changing to be false, but just *to some extent* (σχεδὸν (...) ψεῦδος –

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[1] This is a typical Aristotelian view (cf. *Ph.* 186a24–32; 186b4; *SE* 166b37–167a4, and especially 167a2: οὐ γὰρ ταὐτὸ τὸ εἶναί τέ τι καὶ εἶναι ἁπλῶς), which, however, is drawn from Plato (*Sph.* 255c12–13).

[2] Actually, Parmenides does not explicitly say that "the all is one", but that "it [presumably "being"; see ἐόν at v. 3] neither was nor will be (οὐδέ ποτ' ἦν οὐδ' ἔσται), but is now, wholly homogenous, one, continuous (ὁμοῦ πᾶν, ἕν, συνεχές)" (DK 28 B 8.5–6, transl. N. L. Cordero).

[3] As Booth observes (1957: 2), both Parmenides and Zeno are idealized characters in Plato's *Parmenides*, so we are not compelled to believe that Zeno's arguments were designed to endorse Parmenides' theory on the one. For his part, Cordero contends that Zeno must be taken to be an eristic philosopher, not a *disciple* of Parmenides, and that a Parmenidean legacy in Zeno cannot be detected; see Cordero (2004: 181–182). In this paper, though, these details, albeit important, are not decisive, since my focus is on the way Aristotle took Zeno's paradoxes. Anyway, one always can argue that in the *Parmenides* the character Socrates reminds Parmenides that in a way "Zeno has written the same thing as Parmenides", and that Zeno was trying to fool people into thinking that he states something different. Thus, Plato does not emphasize that Zeno is a *disciple* of Parmenides, but he is concerned with showing (in his own peculiar interpretation) that they are saying the same thing (*Prm.* 128a6–b6). For Zeno's picture derived from Plato's *Parmenides*, see the balanced discussion by Curd (2004: 178–179), who suggests three different but related approaches to Zeno.

[4] As a methodological recommendation Aristotle claims that it would be absurd to try to prove that nature exists, as it is obvious that there are *many* things of this kind (τοιαῦτα τῶν ὄντων ἐστὶν πολλά: cf. *Ph.* 193a3–6). This can be taken to be an overall objection to the Eleatic denial of motion.

[5] Aristotle must have Heraclitus in mind (*Ph.* 265a2–12; see also *GC* 318a18–25).

Ph. 253b6–7); despite it being false, he says, it is less opposed to his own investigation, because, as already established in his treatise on nature (he surely refers to *Ph.* 2), nature is a principle both of movement and of rest, and movement also is a natural phenomenon (φυσικὸν ἡ κίνησις – *Ph.* 253b9)

This paper sets out to explore the way in which Aristotle attempts to reject some Eleatic tenets in general and some of Zeno's views in particular that apparently threaten his 'science of nature'. The Zenonian paradoxes are closely linked to the problem of the continuous and infinity; in *Ph.* 6 Aristotle is intent on discussing the continuity and infinite divisibility of magnitudes, motion and time. He states that Zeno tries to prove (based on a false assumption: ὁ Ζήνωνος λόγος ψεῦδος λαμβάνει – *Ph.* 233a21) that it is impossible for a thing to traverse what is infinite or to come in contact with infinite things in a finite time. Aristotle accounts for why Zeno is wrong by resorting to his distinction between potentiality and actuality and to his theory of mathematical proportions as applied to the motive power and the moved object (*Ph.* VII.5). Regarding the perception of spatial magnitudes, Aristotle states, some very small parts of such magnitudes (that constitute larger ones) are perceived, although he clearly points out that they are perceived only in potentiality, not in actuality. That seems to be the reason why he rejects the Zenonian view that a single grain of millet makes no sound on falling, but a thousand grains make sound, which apparently implies (from Zeno's perspective) that a thousand nothings become something, which is absurd. Aristotle's objections to Zeno, I shall argue, are addressed in order to avoid a potential threat to his science of nature; in fact, if Zeno's paradoxes were true, there would be no motion, but if there is no motion, there is no nature and hence, according to Aristotle, there cannot be a science of nature. My chief claim is that Aristotle did not read the millet seed paradox as a sorites problem or as an issue related to the theory of consciousness; what he actually noted in the millet seed paradox is that it apparently casts doubts on his theory of mathematical proportions, i.e., the theory of proportions that holds between the moving power and the object moved, and the extent of the change and the time taken. If this were not so, it would not become clear why Aristotle establishes an analogy between the millet seed paradox, on the one hand, and the argument of the stone being worn away by the drop of water (*Ph.* 253b15–16) and of the hauled ship, on the other. My interest is not focused on explaining the way in which the paradox should be read, but on showing the difficulty Zeno's millet seed argument would involve *for Aristotle* in the context where he discusses it (*Ph.* VII.5).[6]

The paper proceeds thus: in the following section I provide a brief explanation of the way in which Aristotle appears to have read the dichotomy argument and the Achilles; this can be a nice introduction to Aristotle's theory of mathematical proportions. Within the same section I explain how I think Aristotle considered the millet seed argument and how it, if sound, would complicate his science of nature. In the final section, I provide some general concluding remarks and point out some difficulties regarding Eleaticism (as

[6] As I will point out below, Aristotle also notes that the millet seed paradox involves a perceptual problem.

viewed by Aristotle). The general scope of this paper is rather limited as it will try to show how Zeno's tenet on infinite divisibility would affect Aristotle's view on what nature is or, more generally said, how Zeno's paradoxes release plenty of absurdities by questioning our common sense regarding the physical world, a common sense that apparently must match with Aristotle's theory of the mathematical proportions, such as those proportions are presented in *Ph*. VII.5.

A glance at Zeno's Paradoxes on Infinity as a Background to the Millet Seed Paradox

Before focusing on the millet seed paradox, it would be convenient to briefly refer to two of the best known paradoxes: the 'dichotomy argument' and the 'Achilles' (they are helpful in order to show how I think the theory of proportions and the millet seed argument are linked).[7] As Aristotle himself sums them up, they seem to be designed to prove that there is no motion, since a moving object (τὸ φερόμενον) must reach the half-way stage before it reaches its goal (*Ph*. 239b10–14). This account matches well with the Achilles, since, according to Zeno, in order to traverse any distance, one must always traverse half of the distance in question (this shows, in Zeno's view, that there will be no motion because the moving thing should arrive at the halfway point before the end of the journey; cf. *Ph*. 233a21–31).[8] In accordance with the Achilles,[9] the fastest runner can never reach the slowest, because the former must first arrive at the place from which the slowest runner departed, which means (according to Zeno) that this runner will always be a little farther ahead. If this is so, (*a*) in order to reach the tortoise, Achilles must go through infinite points sorted according to the sequence 1/2, 1/4, 1/8...^{n} ; but (*b*) it is impossible to go through infinite points in a finite time, from which (*c*) it follows that Achilles will never reach the tortoise. To neutralize this argument and block the conclusion (*c*) Aristotle rejects (*b*) by pointing out that there is a sense in which a finite time *is* infinite. According to him, Zeno accepts a false point of departure since he states that it is impossible for a moving object to traverse infinite things (the text says τὰ ἄπειρα, probably in the sense of 'infinite points') or to come into contact with infinite things

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7 In addition to the Dichotomy and the Achilles, Aristotle also refers to the Flying Arrow paradox (*Ph*. 239b5–9; 30: it is impossible for an arrow to be moving during a period of time, because it is impossible for it to be moving at an indivisible instant, a 'now' in Aristotle's jargon; this is false, Aristotle contends, because time is not composed of indivisible nows). He also mentions The Stadium, on which see *Ph*. 239b33–240a15. As Aristotle himself observes, the Dichotomy, the Achilles and the Stadium are closely related to each other; so, for the sake of brevity I will omit the details of these arguments.

8 The argument is summarized by Simplicius as follows: "If motion exists, what is in motion must traverse infinite [points] (ἄπειρα διεξιέναι) in a finite time. But this is impossible; motion, therefore, does not exist" (*in Ph*. 1013.4–6; my transl.).

9 The only difference with "the dichotomy" is that the magnitude remaining is not divided into halves (Arist. *Ph*. 239b19–20: μὴ δίχα τὸ προσλαμβανόμενον μέγεθος).

individually in a finite time. Aristotle maintains that there are two senses in which the word 'infinite' is applied to distance, time, and in general to any continuous thing: 1) in terms of its divisibility and 2) in terms of its extremes. Thus, while a thing cannot come into contact with quantitatively infinite things in a finite time, it can come into contact with infinite things as to their divisibility. In this sense, time itself *is* infinite (*Ph*. 233a28: αὐτὸς ὁ χρόνος οὕτως ἄπειρος). Thus, it turns out that the time used to traverse through the infinite is not finite but infinite, and contact with infinite things is made not in finite but infinite times. So, Zeno's explanation should be rejected because time contains in itself infinite points, and it is not absurd to suppose that infinite points are traversed in infinite time. Therefore, to the one who poses the difficulty (i.e., Zeno) of whether or not it is possible to traverse infinite points (ἄπειρα διεξελθεῖν – *Ph*. 263b4), whether in time or in extension (ἐν χρόνῳ ἢ ἐν μήκει), one can answer that, in one sense, it is possible, while in another it is not. If points *actually* exist, it is not possible, but if they *potentially* exist, it is possible; for example, if a person is moving continuously, she may accidentally traverse infinite points, but not in a strict sense.[10] To be sure, time is infinitely divisible, so Achilles can traverse an infinitely divisible distance and travel the points that mark its divisions.[11] Aristotle's point is that an infinite magnitude cannot be traversed in an finite time, so the bulk of his disagreement with Zeno is that motion or time (two conspicuous examples of continuous items) have parts only in potentiality, not in actuality.

This brief discussion of these well-known Zenonian paradoxes contributes to better understanding, in my view, the millet seed paradox. Aristotle contends that it is wrong to believe (as Zeno does) that there is no part of the millet that does not make a sound since

> there is no reason why any such part should not in any length of time fail to move the air that the whole bushel moves in falling. In fact, it does not of itself move even such a quantity of the air as it would move if this part were by itself: for no part even exists otherwise than potentially (*Ph*. 250a20–21; Oxford Translation, slightly altered).

As is well-known, the argument was rephrased by Simplicius who represents Zeno as engaged in a fictional conversation with the sophist Protagoras; according to Simplicius, Zeno would have argued that if a bushel of millet seed makes a sound, the single

[10] It is irrelevant that there are infinite halves in the line, since the nature of the line is different: a line is what is divisible in one dimension (*Metaph*. 1016b26); every line is always divisible and is a finite extension (*Metaph*. 1020a14). Further, the line is not composed of points because it is impossible for a continuum to be composed of indivisibles, and the points are the limit of the line and so indivisible (cf. *Ph*. 234a24–25). If this is so, Zeno's account of division (which starts from the assumption that a finite line is everywhere divisible and hence any such part of it could be divided further) cannot be true, because any process of division will reach some very small parts of the line which are not further divisible.

[11] For more on this cf. Kirk, Raven, Schofield (1991: 269–276). One of Aristotle's main objections to Zeno is that a period of time cannot be the *sum* of the indivisible instants within it (see n.10 above). But as observed by Schofield (Kirk, Raven, Schofield 1991: 273), Zeno's Arrow argument does not assume that space and time are not infinitely divisible, so Aristotle's objection might be based on a wrong assumption.

millet seed and the ten-thousandth part of a seed (ὁ εἷς κέγχρος καὶ τὸ μυριοστὸν τοῦ κέγχρου) will make a sound as well (Simp. *in Ph.* 1108, 27–28). Some scholars maintain that Zeno's paradox is or can be read as a typical sorites paradox.[12] Others suggest that the issue is related to the theory of consciousness rather than metaphysics or that it can be understood as a *colour sorites* problem.[13] Zeno's millet seed paradox has also been read as a critique of perception, since one can rationally prove that the millet seed makes a sound, even though one cannot perceive such sound. Bearing all of this in mind, we turn to Aristotle's mathematical proportions: if half motive power moves half the object moved a certain distance in an amount of time, it is *not* necessary (οὐκ ἀνάγκη) that half the motive power can move twice (e.g., in weight) half the moved object, half the distance in the same time. Thus, if the motive power moves the moved object a certain distance in an amount of time, it does not necessarily follow that half the motive power will in such an amount of time (or in any part of it) cause the moved object to traverse a part of the distance the object has been moved (see the example provided by Aristotle himself regarding the person moving a ship – *Ph.* 250a16–18 – and briefly analyzed below).[14] This bears the same ratio to the whole of the distance moved as the ratio between the motive power and half the motive power (*Ph.* 250a9–12).

Although Zeno is mentioned several times in Aristotle's works, the millet seed paradox is cited, implicitly or explicitly as far as I know, in only three passages: (i) in *Ph.* VII.5, 250a20–25 (ii) in *Sens.* 6, 445b29–446a20, and (iii) (indirectly) in the *Cat.* 5b15. The two central passages are (i) and (ii). Before advancing in my account of Aristotle's disagreement with Zeno on the millet seed paradox, I will briefly explain the contents of passage (i); for the sake of brevity, I shall omit a detailed discussion of passage (ii), although I will refer to it below, since in the *Sens.* 6 passage Aristotle clearly explains how the paradox is related to a problem of perception.

Philosophers and historians of science have thought that in Aristotle's *Ph.* VII.5 we can observe the first formulation of the basic laws of quantitative movement. Some people even take the text somehow to describe the history of the passage from a qualitative consideration of nature (the Aristotelian one) to the new quantitative conception of the physical sciences in Modernity.[15] According to Treder, for both Aristotle and Newton

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[12] Barnes (1982: 203–204). See, however, Barnes (1982: ix), where he retracts from what he had said in the 1979 edition of this book (in fact, a Sorites puzzle always contains a vague term, which is not the case with the millet seed argument, as recognized by Barnes himself on p. 204). Against the soritical reading of Zeno's paradox, see also Barnes (2012: 551), where he argues that Zeno did not proceed by way of a soritical argument, but by the aid of a principle of proportionality. This is the view I shall be defending, i.e. that Aristotle took Zeno's paradox to break his own mathematical proportionalities as applied to the motive power and the moved object.

[13] Mortensen (2007: 17).

[14] Aristotle's point is that, from the fact that several haulers can move a ship, one cannot infer that one hauler can move part of the ship alone. For discussion and Archimedes' objection to Aristotle see Berryman (2019: 119 and especially 187–191).

[15] See Treder (1988: 113–122). For discussion of Aristotle's mathematical proportions (as presented in *Ph.* VII.5) see Wardy (1990: 314–327) and De Groot (2014: 274–281).

every change of state requires a 'sufficient reason'; in Aristotle, Treder insists, the change of state is the place of a body and, according to the Aristotelian axiom of movement, he contends, force and speed are proportional (the reference is probably to *Ph.* 250a1–10, although Treder does not cite here or anywhere else in his study any reference to Aristotle's texts).[16] In Newton, on the other hand, the state is the amount of movement (the impulse) of the body, and its change (as in Aristotle) implies a force that is proportional to the acceleration.

Although it is possible to establish – as Treder suggests – certain structural coincidences between the Aristotelian physics and modern physical science, it must be recalled that Aristotle never sets out to formulate in a *strict* mathematical way his ideas about the relation between the moving power (τὸ κινοῦν) and the moved object (τὸ κινούμενον), the distance traversed and the amount of time taken by the moved object. Regardless, it might be said generally that *Ph.* VII.5 contains Aristotle's 'quantitative formulation of movement';[17] what is clear in this passage is that what is moved is something endowed with weight (*Ph.* 250a25–b27). Further, in Aristotle's view the scope of his 'quantitative laws' of movement extends also to 'qualitative movements'; indeed, when describing what a 'greater power' is (ἡ πλείων δύναμις), he states that it is that which always produces an equal result in less time (and this may be so in the case of heating, sweetening or throwing; *Ph.* 266a26–28). Thus, it is clear that the power that moves something else is not a power that *only* provides locative movement, so while assessing the scope of Aristotle's 'quantitative laws of movement', one should consider the fact that they are valid both for locative and qualitative movement (see *Ph.* 250a8–b7). In his discussion of forced motion (*Ph.* VIII.10) Aristotle concentrates on constant speeds and, as Owen observes,[18] makes no mention of resistance to the medium. In fact, Aristotle's intention seemingly is to make a generalization about *all* kinds of change and not just to focus on locomotion. He assumes that the velocity of motion (regarding the considered cases) is uniform and that the proportions will be those indicated, provided there is no external factor preventing quantities from being related in that way; he also clearly points out that the power of the mover A and the weight of the object moved B are in a similar rela-

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[16] This issue was recently discussed by Rovelli (2015). Rovelli argues that, contrary to what is usually stated, the distinction between a natural and violent motion to some extent survives in the first two laws of Newton. Further, Rovelli even states that "Aristotle is perfectly correct in evaluating the falling velocity as something that depends directly on the weight" (Rovelli 2015: 30). Rovelli takes pains to show that, *mutatis mutatndis*, even though Aristotle's physics is far from being perfect, "*it is similar* to Newton's and Einstein's physics, which are far from being perfect either" (italics are mine; Rovelli 2015: 30; see also p. 32–33, where this suggestion is developed). Indeed, I do not have the competence to assess the scope of this comparison. Still, for someone with limited knowledge of contemporary physics like myself, this kind of assessment of Aristotelian physics, read in the light of Newtonian and Einsteinian physics, is striking.

[17] There are other isolated references to this issue in the *Corpus Aristotelicum* (*Cael.* 274b34–275a10 and *Ph.* 266a13–b24), but such passages contain no mention of weights in motion (a detail that is essential in the discussion of *Ph.* VII.5).

[18] See Owen (1986a: 323).

tion (that is, the strength must be proportional to the weight: ἀνάλογον ἡ ἰσχὺς πρὸς τὸ βάρος – *Ph.* 250a8–9).[19]

But the core of *Ph.* VII.5 is the proportionality between power and speed, not between power and *acceleration*. Aristotle's thesis is that the distance through which an object is moved by a moving power is proportional to that power and to the time in which the power is exerted. Additionally, the distance is in inverse proportion to the magnitude of the object moved; it is not so clear that Aristotle has taken resistance into account, so, unlike what Aristotle believes, it is the motive power which determines acceleration.[20] What he probably ignored is that a minimum power is required to overcome the friction of a body which is at rest, and that such friction is generally greater than that of the body in motion. However, even though he noted the relationship between the moving power and the weight of the moved object (insofar as he notices that if the moved object exceeds the strength of the motive power, the moved object must be moved slowly, and if it is surpassed by the motive power, it is moved quickly; see *GA* 787a15–18), this does not mean that he has taken into account the problem of friction as a theoretical issue that needed to be analyzed in the explanation of locative movement.

In addition, it should be noted that Aristotle did not have the concept of acceleration as it was thought of by Newton and modern physics in general, i.e. the ratio of the change in speed to time; nor was Aristotle interested in explaining the relation between moved object, motive power, and distance traversed in terms of 'laws'. One must not lose sight of the fact that Aristotle's *Physics* is *not* a treatise on physical science in the ordinary sense of the term, but a study analyzing philosophically (by making use of strong metaphysical ingredients, such as actuality-potentiality, matter-form distinctions) all the entities that are in motion. Actually, it is a qualitative physics with some isolated quantitative expressions, such as those found in *Ph.* VII.5.

Now the bulk of the millet seed argument consists of asserting that one should not ascribe to the part the same property that one attributes to the whole. Interestingly, when

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[19] Thus, according to Owen, Aristotle seems to infer quite naturally that the continuous application of a moving power of A (the moving power) on B (the moved magnitude) is sufficient to overcome the resistance of the weight due to gravity, friction and the medium; cf. Owen (1986b: 156; 1986a: 330). This, however, is not so clear; in fact, what the text says does not mean that Aristotle has recognized friction (that is, the power that is found in connection with the common limit of two bodies that are in contact, a power that resists the movement of one body with the other) as a separate factor in movement. As suggested by Sambursky, one of the main reasons why the Ancients did not discover the correct laws of dynamics was that, in establishing relations between forces as causes of motion and the resulting motions, they did not take into account the opposing forces of friction; cf. Sambursky (1962: 64–65). More recently, De Groot (2014: 240–241), while commenting on Duhem's interpretation of Aristotle's theory of proportions, points out that Duhem thought to have found in the (Ps. Aristotelian) *Mechanics* Aristotle's principle that, for the same force acting on different bodies, the velocities imparted are inversely proportional to the weights of those bodies. This would show that, if *Mechanics* was written after Aristotle (as it surely was), the Aristotelian theory of proportions (as reconstructed from *Ph.* and *Cael.*) was still valid. Although De Groot deals with the issue of "dragging" (as one of the four movement related to 'being moved by another'; see *Ph.* II.2, 243a17: ἕλξις; De Groot 2014: 287–288), she does not address the problem of friction, which seems so decisive in assessing the limitations of the Aristotelian theory of motion.

[20] It is not entirely clear how Aristotle gets his proportions; he only says that it must be so, otherwise the proportion will not be preserved (ἀνάλογον – *Ph.* 250a3–4, 28 and also *Cael.* 275a7–14).

commenting on the millet seed passage, Philoponus places emphasis upon the fact that if the grain of millet is taken by itself (i.e., as a part: τὸ μόριον καθ' ἑαυτό), it will not produce the part of the whole movement that it would produce if taken with the whole bushel. It moves that way in the whole, but it is *potentially* in the whole.[21] Likewise, a grain of millet and a single individual hauling a ship, in being in the whole as parts, somehow (τι) jointly contribute to the movement *of air* (Philop. *in Ph*. 881.4–5; this detail is relevant for reminding us of the problem of perception, clearly implied in Zeno's paradox according to Aristotle's discussion in *Sens*. 6; see below). Thus, the part, although it is in the whole, is nothing by itself, for it does not work as a mover by itself within the whole, inasmuch as it is only potentially in it. Philoponus compares the parts of a word with the individual hauling the ship:[22] a part will not produce any movement by itself but, in being in the whole as matter, jointly introduces something that contributes to the movement of the whole (*in Ph*. 881.9–16).

For his part, in his commentary on Aristotle's *Ph*. VII.5 Themistius wonders whether the totality will move a weight proportioned to the weight derived from individuals; this means that if each person moves a one-talent weight, it would seem reasonable that one hundred individuals as a whole move a hundred-talent weight. It is not reasonable for it to be less, but to be greater, for it is more reasonable that what is collective and 'ambitious' (τὸ ἀθρόον καὶ φιλότιμον) is also at the same time capable of 'mutual stimulation' (παρορμητικὸν ἀλλήλων), just as horses yoked together achieve more speed when a greater power supervenes because of the intensity of the animals (Them. in *Ph*. 208.15–17); in other words, a collective power is always greater than a divided or 'isolated' power (ἀεί τε ἡ ἀθρόος δύναμις πλείω τῆς μεμερισμένης – Them. in *Ph*. 208.5).[23]

Both commentators concentrate on the fact that a grain of millet, as a part of the whole bushel, is what it is potentially, and if this is so it cannot act as a mover *by itself* within the whole. Further, a grain of millet can stop moving the air that produces the sound a distance equal to the motion made by the whole measure (the millet measure); as Aristotle says, it can stop moving the air (*Ph*. 250a21–22). Proportion is not preserved because a separate unit of the bushel will not move that part of the air it moves when it is a part of the bushel (i.e. part of the whole). In fact, as a part, it only exists in the whole in potentiality.[24]

As just mentioned above, the millet seed paradox also introduces a problem related to perception: according to Aristotle, the tiniest part of millet cannot make a sound since

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[21] Philop. *in Ph*. 881.9–12. The part, Aristotle argues, has only a potential existence in the whole (δυνάμει ἐν τῷ ὅλῳ – Arist. *Ph*. 250a24–25).

[22] Such as the parts are not significant by themselves (καθ' αὑτὰ μὲν ἄσημά ἐστιν), but each part, in being in potentiality as matter in the whole, contributes to the meaning of the name, so too the person who hauls up the ship will move nothing by himself (*in Ph*. 881.12–15).

[23] In the paraphrase of this Themistius passage I am drawing on Todd's translation of this text; see Tood, (2008).

[24] For this approach, see Wardy (1990: 323).

there is no reason why any part (ὁτιοῦν μέρος) should be able to move in any amount of time any amount of the air which the whole bushel (ὁ ὅλος μέδιμνος) moved as it fell (*Ph*. 250a20–22). Clearly, the assumption is that the noise made is proportional to the amount of air moved; in fact, for Aristotle there must be a portion of air involved in the production of any noise, since the air is a continuous quantity and is able to set the sense organ in motion (*de An*. 419a13–15). The portion of the bushel does not move the quantity of air it would move if it were by itself because within the whole bushel no portion exists, except potentially. This matches quite well with Aristotle's account in the *Sens*. 6; in fact, he thinks that putting forward the infinite divisibility of magnitude (whether perceptible qualities are infinitely divisible or not) involves serious problems. Aristotle wonders if every body is infinitely divisible; if so, it would appear that its perceptible qualities (color, flavor, odor, sound, weight, cold or heat, heaviness or lightness, hardness or softness, and so forth) are infinitely divisible, as well. This, though, cannot be the case, since each of these produces perception (in the sense that each of these activates a sense power) and if their power (δύναμις) is divisible, our perception of them should likewise be divisible to infinity, and every part of a body should be a perceptible magnitude (*Sens*. 445b3–10). Any magnitude must be perceptible; if not, it would be possible to see a thing which is white but not of a certain quantity (which is absurd, since the bearer of qualities is a bodily substance). Thus, there cannot be a body without color, weight, or any other quality, since, if this were possible, perceptible objects should be taken to be composites of non-perceptible parts (*quod non* for Aristotle).

Now Aristotle's main interest is focused on the fact that a continuum is divisible into an infinite number of unequal parts. That which is not by itself continuous is divisible into species which are finite (πεπερασμένα) in number (*Sens*. 445b27–29). Since properties (i.e. the perceptible qualities of bodily things) must be taken to be species and given that continuity (συνέχεια) always exists in these, one must admit that what is in potentiality differs from what is in actuality. That is why, Aristotle concludes, when one *sees* a grain of millet, its ten-thousandth part turns out to be unnoticed by sight (*Sens*. 445b31–446a1). For the same reason, the sound contained in a quarter-tone escapes notice; what one can hear is the *whole* strain (ἀκούει τοῦ μέλους παντός), as it is a continuum (συνεχοῦς ὄντος). What escapes one's perception is the interval between the extreme sounds. This, Aristotle contends, is enough to prove that extremely small perceptive ingredients (τὰ μικρὰ πάμπαν; 446a5) are unnoticed, and this is so because they are potentially, not actually, perceptible (when they are not separated from the wholes). The way in which Aristotle deals with the millet seed paradox in *Sens*. 6 shows that he did think that a serious problem regarding perception was involved in it. Thus, when Zeno holds that a single millet seed makes no sound in falling but a thousand seeds make sound, he is at odds with perceptual phenomena.

This being so, if within the whole bushel no portion even exists, except potentially, and if Zeno is right (*quod non* in Aristotle's view), the proportion is not preserved; such a proportion is preserved if in an equal amount of time an equal motive power moves half a moved object double the distance traversed, and moves half a moved object over the distance it has moved in half the amount of time it has taken (*Ph.* 250a3–4: οὕτω γὰρ ἀνάλογον ἔσται). The analogy with the argument of the stone being worn away by the drop of water and of the hauled ship now turns out to be clearer: the fact that the drop of water has worn a certain amount of the stone does not imply that half of the drop will remove half that amount of stone in half the time. The same goes for the haulers of the ship: the movement of the ship is due to a kind of simultaneous and 'cumulative' effort, as it were, of the many persons hauling the ship; thus, it should not be inferred that each hauler in particular moves the ship lightly. Similarly, and *mutatis mutandis*, it is not the case that, if a bushel of millet seed makes a sound, the single millet seed and the ten-thousandth part of a seed will make a sound, too.[25]

How 'contrary to nature' are Eleatic Tenets for Aristotle? Concluding Remarks

As observed above, while assessing the scope of Aristotle's 'quantitative laws of movement', one should consider the fact that they are valid both for locative and qualitative movement. Defining a 'greater power' (ἡ πλείων δύναμις), he asserts that it is always the one producing an equal effect in less time, such as heating or sweetening or throwing (*Ph.* 266a26–28). As is clear here, the power that acts upon something else is not a power that only provides locative movement. In fact, there is an agent of increase and an object increased; the former causes increase, and the latter is increased in a certain amount of time and to a certain extent. The same goes for the agent of alteration and what is altered (see *Ph.* 250a28–b7). But Aristotle's important point here (which can be read as a rejection of Eleaticism) is that in the case of increase and decrease the process cannot be continuous; rather there must be intermediate periods in which there is neither increase nor decrease. From the fact that decrease is infinitely divisible, it does not follow that some part must always be destroyed (a whole can be destroyed at a certain moment); the same will occur with alteration itself: in fact, it often occurs all at once, as in freezing (*Ph.* 186a14–16; 253b23–26). Aristotle's point is that water passes from one state to the other as a whole, and if this is so, there must be a first part that freezes and hence alteration is possible.[26]

This kind of argument, if it is read as an objection to Zeno's paradoxes on infinite divisibility, intends to show both that such paradoxes are contrary to Aristotle's conception of nature and (what is probably worst of all) that to argue that alteration is continu-

[25] The argument is even clearer if it is recalled that this debate is included in the passage where Aristotle is examining alteration and arguing against the possibility that alteration is continuous; on this point see Bolotin, (1998: 67–68). I return to this issue in the next section.

[26] As observed by Bolotin (1998: 62), if everything that changes is divisible, one should assume infinite divisibility, since the changing being as a whole can also be applied separately to each of its changing parts, and to the parts of those parts, and so on. But Aristotle thinks that there are changes (e.g., alteration) in which a being is transformed simultaneously in all its parts.

ous is too much at odds with 'evident facts' (τοῖς φανεροῖς ἀμφισβητεῖν – *Ph.* 253b29–30; 254a8), for alteration goes from one contrary to another.[27] If the Eleatic rationalization of the natural world is endorsed, natural phenomena cannot be explained. This, though, does not mean that Aristotle dismisses the Eleatic view of the world at all (in fact, he acknowledges that what the Eleatics argue contains a certain philosophical interest – *Ph.* 185a20); such a view turns out to be important for Aristotle's purposes in the elaboration of his account of nature. Indeed, some important issues that he seriously considers when determining the basic principles of his 'science of nature' are closely related to his critique of the Eleatics. For example, Aristotle takes advantage of his discussion with Parmenides in a constructive manner in favor of his own theory of change and of the indispensable conditions for the constitution of a science of nature. One of the crucial Aristotelian disagreements with Parmenides (his theory of being) is at once one of the most fertile issues from the standpoint of Aristotle's use of such disagreements in order to establish and develop the foundations of his physics.[28] This explains why Aristotle takes pains to show why, even though the Eleatics are not really concerned with nature, given that they sometimes point out certain problems which are important to the study of nature, it might be good to debate their theories, as the investigation contains some philosophical interest. However, although the Eleatic views have a certain philosophical interest (insofar as they put forward physical issues, such as motion, change, the infinite, etc.; *Metaph.* 986b17–987a2), they ultimately miss the mark.

As indicated at the beginning of this paper, an important imputation that Aristotle makes against Parmenides is that he ignores the φαινόμενα.[29] It is a charge that he also makes against the Pythagoreans who, while constructing another earth in opposition to ours (the 'counter-earth' – ἀντίχθων), they are not seeking explanations and causes in order to account for the phenomena (οὐ πρὸς τὰ φαινόμενα τοὺς λόγους καὶ τὰς αἰτίας ζητοῦντες), but forcing the phenomena and accommodating them to certain explanations and opinions of their own (*Cael.* 293a23–27). Now, when referring to the counter-earth the Pythagoreans are not paying attention to what seems to be the case, both in the sense of common opinions and in the sense of what is manifestly observed at the most basic level of sense perception (cf. *Cael.* 297b23–24: διὰ τῶν φαινομένων κατὰ τὴν αἴσθησιν; see also 306a16–17).

Nevertheless, this is also the criticism Aristotle addresses against Parmenides in *Ph.* VIII.3: for a theoretical explanation to be defensible and truly explanatory, it must have

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[27] For Aristotle any change (including alteration, of course) involves opposites, so it does not continue as one and the same change forever; *Ph.* 252b28–30.

[28] For this kind of methodology in Aristotle (but focused on the domain of physics), see, for instance, *Cael.* 298b14–17, where he ascribes both to Melissus and Parmenides the view that there is no generation and destruction, but "it only seems to us" (ἀλλὰ μόνον δοκεῖν ἡμῖν). According to Aristotle, the Eleatics maintain that nothing that is (οὐθὲν (...) τῶν ὄντων) is subject to generation or destruction, but in Aristotle's view this stance is, once again, utterly refuted by the evident facts themselves.

[29] Although, in a certain sense, Aristotle thinks that Parmenides himself, being forced to follow the phenomena (*Metaph.* 986b31: ἀναγκαζόμενος δ' ἀκολουθεῖν τοῖς φαινομένοις), and assuming that what is is one (reading

a connection with the phenomena and with what perception indicates to us in the phenomenal domain. The Eleatic considerations of nature rely more on reasoning than on perception; Zeno's paradoxes can be taken to be refined reasonings that theoretically show that there is no motion, but in fact things move, i.e., they are subject to change. One can formulate a very sophisticated theory about nature (like the Eleatic one), but if one does not respect the Aristotelian prescription, according to which any philosophical theory must respect what phenomena indicate, such a theory cannot be part of the 'science of nature'.

Aristotle insists that, in fact, some things are subject to change, so to maintain that everything is in permanent rest is to go against our perceptual capacities that clearly point out the opposite, and implies a kind of 'softness of mind' (*Ph*. 253a33–34: ἀρρωστία τίς ἐστιν διανοίας). Aristotle cannot be more emphatic when asserting that the tenet that there is no motion at all is both contrary to perception and to the study of nature; further, it is a thesis contrary to the 'physicist' (πρὸς τὸν φυσικόν) in addition to all the other sciences, as they all make use of motion. The reference to mathematics (in *Ph*. 253b2–6) is the same as that which Aristotle made earlier in *Ph*. I.2 (184b25–185a3): neither the physicist nor the mathematician is interested in objecting to the principles of their respective sciences, because without indemonstrable principles the constitution of a science is inconceivable. So, there is no 'scientist' (no matter his field of expertise) who is interested in responding to the denial of the object of his science.

At this point it is much clearer why Aristotle holds that the 'basic assumption' of physics is that nature is the principle of motion (the subject had already been demonstrated and discussed at length in *Ph*. II.1, but his debate with Eleaticism contributes to showing how this is effectively the case). What Aristotle is surely stressing is that a true principle of physical science is to start from the fact that science of nature takes motion for granted, motion understood in all possible senses (substantial, qualitative, quantitative, or local). In Aristotle's view, I think, Eleaticism understood as a theory interested in explaining what nature is should be taken to be a 'successful failure':[30] it is a failure because it ignores the basic assumption of the science of nature (i.e. "there is motion") and thereby it is unable to account for natural processes. On the other hand, that failure is 'successful' (i.e., successful for Aristotle's project) because without an Eleatic philosopher stating that there is no motion, it would have been much more difficult to reach the intermediate (and 'more reasonable') position, according to which there are things that are in motion and others at rest.

τὸ ὂν ἕν with the Greek commentators) conceptually (κατὰ τὸν λόγον), but many according to perception (κατὰ τὴν αἴσθησιν), posits the hot and the cold (i.e., fire and earth) as causes and principles.

[30] Indeed, the Parmenidean philosopher always might argue that Parmenides' main purpose was not to explain what nature is and how natural process occur; but Aristotle certainly assumed that the Eleatic metaphysics (as his own metaphysics does) should be able to account for the natural world and its functioning.

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Aristotle, Eleaticism, and Zeno's Grains of Millet

This paper explores how Aristotle rejects some Eleatic tenets in general and some of Zeno's views in particular that apparently threaten the Aristotelian "science of nature." According to Zeno, it is impossible for a thing to traverse what is infinite or to come in contact with infinite things in a finite time. Aristotle takes the Zenonian view to be wrong by resorting to his distinction between potentiality and actuality and to his theory of mathematical proportions as applied to the motive power and the moved object (*Ph.* VII.5). He states that some minimal parts of certain magnitudes (i.e., continuous quantities) are perceived, but only in potentiality, not in actuality. This being so, Zeno's view that a single grain of millet makes no sound on falling, but a thousand grains make a sound must be rejected. If Zeno's paradoxes were true, there would be no motion, but if there is no motion, there is no nature, and hence, there cannot be a science of nature. What Aristotle noted in the millet seed paradox, I hold, is that it apparently casts doubt on his theory of mathematical proportions, i.e., the theory of proportions that holds between the moving power and the object moved, and the extent of the change and the time taken. This approach explains why Aristotle establishes an analogy between the millet seed paradox, on the one hand, and the argument of the stone being worn away by the drop of water (*Ph.* 253b15–16) and the hauled ship, on the other.

KEYWORDS

Aristotle, Eleaticism, Parmenides, Zeno, motion, mathematical proportions