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Teleology Without Tears: Aristotle and the Role of Mechanistic Conceptions of Organisms

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I Introduction

In this paper I outline a role for mechanistic conceptions of organisms in ancient Greek natural philosophy, especially the study of organisms. By 'mechanistic conceptions' I mean the use of ideas and techniques drawn from the field of mechanics to investigate the natural world. 'Mechanistic conceptions' of organisms in ancient Greek philosophy, then, are those that draw on the *ancient* understanding of the field called 'mechanics' — *hê mêchanikê technê*—to investigate living things, rather than those bearing some perceived similarity to *modern* notions of 'the mechanical.' I have argued elsewhere that evidence of mechanistic conceptions of the natural world can be found, not only among seventeenth and eighteenth century 'mechanical philosophers,' but also—albeit in vestigial form — in some ancient Greek texts.[1] Unfortunately, these reports are slight, often by detractors of this approach, and offer only clues as to the motivational context for employing these

1 Berryman (2003); Berryman (2002b)

mechanical conceptions. Here, my purpose is to suggest what role they might have played in the history of natural philosophy.

Against the background of some tensions within Aristotle's biology, I consider how 'mechanistic conceptions' of the natural world could be seen to offer a resolution to a difficulty highlighted, but never resolved, in Aristotelian natural philosophy. Natural philosophers in Aristotle's wake could reasonably have seen the potential of 'mechanical models' to resolve that tension. My aim here is to work out a possible function for such models, rather than to argue that they did in fact play this role in any particular period: to formulate a position in conceptual space, rather than to document specific views that were articulated in historical time.

Few approaches to the investigation of natural things in antiquity avoid both the Scylla of denying the existence of teleological explanations, and the Charybdis of claiming that there are causal gaps in any material account that are filled by unanalyzable teleological properties. At the one extreme are those who deny the necessity for teleological accounts altogether; at the other are those who insist that teleological analyses include components — powers, natures, capacities — needed to fill efficient-causal gaps in the material account, and whose function cannot be analysed in terms of the material properties in which they are realized. There are, of course, positions between these two extremes, but few ancient natural philosophies seem to have found a stable middle ground. This paper will argue that the appeal to mechanics would have made it seem plausible, in late antiquity, that such a middle ground be tenable. The conception of the natural world as working *like* a mechanical device offered a way that material processes might produce goal-directed effects, without the price associated with other notions of teleology.

Some of the major interpretative difficulties surrounding Aristotle's natural philosophy generally, and his account of organisms in particular, center precisely on the relationship between his teleological explanations and the material, nonteleological accounts of phenomena that he also recognizes. Anger, he tells us, is a goal-directed desire for revenge; it is also, considered materially, a boiling of the blood around the heart. Neither explanation is dispensible or subsumed by the other: both are studied in equally legitimate fields of inquiry. Beyond this there is no consensus, however, and scholars have proposed different interpretations of the relationship between Aristotle's material and teleological accounts. Some take Aristotle to allow that material processes might be sufficient to produce a given outcome. Others regard him as introducing irredeemably teleological notions as explanatory primitives, needed to fill efficient-causal gaps in a material account. Controversy continues.

Here, rather than attempting to resolve this dispute in favour of either interpretation, I suggest that a tension genuinely exists within Aristotelian natural philosophy. Aristotle might, that is, have recognized the desirability of occupying some 'middle ground,' without ever succeeding in doing so. I suggest that 'mechanistic conceptions' offer a route towards this goal.

II A Middle Ground

Rather than define a 'middle ground' in positive terms and risk limiting unduly the ways to occupy it, I characterize it negatively via two excluded extremes.[2] One extreme it avoids is to deny what has seemed to many to be an important fact about the functioning of organisms: that their parts are best understood as performing a given function or working towards a goal. Ancient materialists had few resources to explain how complex, well-adapted structures were regularly produced in nature; attempts to explain how functionally adapted organisms developed by unplanned, material processes seemed to many both implausible and incomplete. The other extreme would be to despair of giving any nonteleological analysis of these capacities, i.e. of showing how they come about by material necessitation. By positing irreducibly teleological properties as explanatorily basic, some of Aristotle's interpreters — like Molière's doctor with his dormitive virtues — seem too easily to deny that natural processes are susceptible of meaningful investigation, or that we can understand how functions and goals are realized by material processes. Postulating powers whose existence is only manifest in the phenomena they purport to explain is to assume a heavy burden of proof.[3] Denying the possibility of a nonteleological account of organic processes, moreover, effectively baffles any attempt to understand how living things could be composed from or have arisen from the same matter as the nonliving world: it draws a distinction in

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2 Others have described Aristotle as seeking a 'middle way' between materialism and Plato's teleology: see, e.g. Hankinson (1998, 125), to which my understanding of the issues owes much.

3 That this is the real problem with some appeals to dispositional properties, see Mellor (1991). Matthen (1989, 163) identifies a related problem with postulating powers as explanation: relying on irreducible powers makes it impossible to give a complete specification of causes, because powers can be prevented from producing their effects.

kind between living and nonliving things that is mysterious and closed to further investigation.[4] Both extremes have their price.

The ancient atomists are the school most clearly identified with the view that the properties of the most basic material components suffice to account for everything. Democritean atomism did have some resources for showing how apparently goal-directed processes arise from the collision of atoms. Democritus' idea that the motion of atoms results in a cosmic whirl or vortex seems to be intended to explain how apparent regularity can arise from unordered motions of individual atoms.[5] The vortex seems to be offered as a case where individual motions result in an overall pattern of centripetal motions, leading to the 'separating out' of atoms of different sizes and shapes.[6] The atomist account of the motion of 'like to like' cites further evidence that apparently goal-directed sorting by size and shape can be produced by random collision, like grains winnowed in a sieve.[7] Remarks by Aristotle suggest that even Democritus anticipated the idea — formulated explicitly by Lucretius — that the apparent attraction of bodies into a void can be explained away by the chaotic collision-driven motion of atoms.[8] Atoms have no active tendencies towards order; they neither seek their like nor seek to fill a void. The atomists' successes in explaining away these apparently goal-directed processes depend on a distinction between perceptible appearances at the macroscopic level and the genuine, efficient-causal processes at the atomic level. The macroscopic effects — centripetal force, clustering of likes, attraction — are all, Democritus might say, merely apparent; the reality at the level of the atoms moving in a void exibits no such features.[9]

Despite atomism's successes in accounting for some apparently goal-directed macroscopic effects by nonteleological means, ancient materialists notoriously had difficulty accounting for the regular reproduction of functional forms in organisms. According to Aristotle, the strongest materialist attempt to account for the suitability of organic parts to

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4 This view is put most succinctly recently in Burnyeat (1992, 26).

5 ps-Plutarch *Ep*. 1.4 = DK 67A24; Diogenes Laertius 9.30-33 = DK 67A1; Philoponus *in Phys*. 262.8-13; see Taylor (1999, 94-103).

6 Kirk, Raven and Schofield (1983, 419-20); Heath (1913, 81, 122).

7 Sextus Empiricus *AM* 7.116 = DK 68B164; ps-Plutarch Ep. 4.19.3 = DK 68A128. See Furley (1989, 79).

8 Alex. Aphr. *Quaest*. 2.23; Lucretius *DRN* 6.1022-41; see Berryman (2002a).

9 One of Lucretius' first arguments is to show that we accept the idea of imperceptible processes producing perceptible results, even where we do not know the detailed process involved: *DRN* 1.265-328.

functions originated with Empedocles. Empedocles claimed that, at one time, complexes formed haphazardly from wildly varied combinations of parts, suitable or not; those combinations of parts that happened out to constitute a viable whole were the ones that survived.[10] Complex structures do not come to have the form they do in order to fulfill a given function; functions are acquired later, once particular forms come to exist. The generation of a functional form has, *per se*, no explanation: it is merely a chance variant, produced by the same kinds of material causes as dysfunctional forms.[11] This solution seems to have been that adopted by the atomists. Empedocles' solution, however, depends on supposing that, at one time, a considerable variety of different forms were produced, although the regular reproduction of forms is now the norm. Accounting for the difference, and for the latter situation, are still open problems, as Aristotle recognized. It goes some way to suggest how an account of the occurrence of suitable forms could be given in nonteleological terms, but cannot provide the further step of showing how they are now *regularly produced*, and *regularly develop* into functional forms.[12]

Explaining not only the production of suitable forms, but also their reproduction, was thus a critical problem for nonteleological materialisms.[13] In ancient theories of sexual reproduction, it is generally agreed that seed, *sperma*, is somehow responsible for the creation of a new entity resembling its parents. The problem for materialists is to show how seed could reproduce form by non-goal-directed, material processes. Ancient theories differ on whether both parents produce seed, or only the male[14]; whether seed is drawn from the whole body or only one part[15]; and how seed effects the subsequent development of the embryo.

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10 Aristotle *Physics* 2.8, 198b24ff.

11 Aristotle *DC* 3.2, 300b25-31.

12 Aristotle *Physics* 2.8, 199b1ff.; Sorabji (1980, 179-81).

13 It is sometimes argued — e.g. Hirsch (1990) — that, before Plato and Aristotle, there were no developed teleological systems for materialists to be reacting against. However, the attempt to explain nature without imputing intentional design provides a sufficient motivation for the issues in question here.

14 Proponents of the former view had also to explain how the contributions from two parents were reconciled.

15 Proponents of the former view took the samples either to be independent or to be formed into a miniature specimen: but the differences between what came to be called the 'pangenetic' and 'preformationist' versions of the 'sampling' approach (Preus, 1970; Tress, 1992) was less central than the controversy over material versus immaterial processes of transmitting form.

Aristotle criticizes theories of sexual reproduction common among Presocratic materialists.[16] Rather than treat the seed as a single entity directing the development of the embryo as a whole, a common materialist strategy treats it as a composite drawn from all parts of the body. This view could be held in conjunction with the view that both parents contribute seed, and that the parts of the resulting embryo could be formed from the contribution of either parent.[17] The intention is to explain the fact that children can resemble either parent, even the parent of the opposite sex, and that they often share characteristics of both. Its proponents also try to explain how mutilations — acquired changes in particular parts — can be inherited, as was then believed.[18]

Aristotle offers a number of criticisms of the general strategy that regards seed as a material sampling of all parts of the organism, rather than a kind of formal blueprint encoding the future development of the organism holistically.[19] Some are programmatic, referring to the lack of a principle of composition of organs, or to the implausibility of treating the body as if it were a composition of detached parts.[20] But others are criticisms of the adequacy of the 'sampling' approach to fit the observed data, and would be problems any materialist would need to acknowledge. One is that parents reproduce before they have acquired certain characteristics, like beards or grey hair, yet these traits are passed on to their children. The implication is that characteristics like these must somehow be encoded immaterially in the form, since they are manifestly not instantiated in a sample of the matter as it exists at the time

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16 *GA* 1.18, 725a22. Although he mentions only Empedocles and Anaxagoras by name in *GA* 1.17-18, other evidence suggests that it is also the view held by Democritus and Praxagoras: Galen *De Defin. Med*. 439 (K19,449)=DK 68B 124; ps-Plutarch *Ep*. 5.3.6=DK 68 A141; cf. also *Genit*. 1,3.

17 Democritus' theory is distinct from Empedocles' here on whether the seed of each parent contains pieces from every part, or only from half: Philoponus *in GA* 167,13. Cf. von Staden (1989, 230-31), on whether reports that Pythagoras or Democritus held a two-seed theory are anachronistic reflections of Herophilean views, and if the reference to the seed-producing 'assistants' found in the female (*DRN* 4.1209-59) is a later interpolation.

18 The inference from the experience of pleasure can be argued either way. For a more careful treatment of the materialist arguments against the background of the Hippocratic view, see Preus (1977); Morsink (1979).

19 *GA* 1.18, 722a5-8.

20 *GA* 1.18, 722a29ff, 722b30; Preus 1970. As Aristotle sees the alternatives, the samples drawn from parts of the parent are either detached and haphazardly arranged, or the seed is essentially a miniature animal. The latter alternative has problems showing how two seeds can combine, or why a female cannot procreate alone.

of reproduction. Further evidence for this is that characteristics can be inherited across generations.

These objections help clarify Aristotle's understanding of the strategy of the materialists: they think of seed as a sample of the relevant kind of stuff, present throughout, which merely grows into a larger version of itself. Seed, on this view, is no abstract form which could be realized in successive stages of development, but literally a 'chip off the old block.' The properties transmitted are those manifestly present in the matter as it currently exists, not those encoded in an abstract form and in such a way that they might not be manifest.

The weakness of ancient materialism, then, is that its best account of reproduction cannot depend on some kind of encoded form that can normatively regulate the subsequent development of the organism, but can only explain reproduction as a process of 'sampling' the matter with its occurrent properties. Growth, on this view, is not the unfolding of an abstract form, but the increase of an existing sample of matter. Seed, understood as a composite sampling of all tissue types in an organism, could grow either by attracting like material to each part of it, or by assimilating matter that is unlike.[21] Aristotle questions the usefulness of assimilation strategies here: if the seed grows by *transforming* external matter, what is the benefit of supposing that the seed is like in kind to the parts, rather than something different acting on it? More reasonably, the materialists were likely relying on the idea that 'like tends to like' to account for the growth of parts from the seed.[22] Democritus seems to have held that a seed contains parts of homoiomerous tissues, i.e. bones, flesh, sinew;[23] it seems that he employed the attraction of like atoms to like to explain the accumulation of homoiomerous tissues around the initial sample.

But even if the atomist account made it plausible that seed, because it contained samples of various tissues, could serve as a locus for the accumulation of more of those tissues, it cannot account for their arrangement into organs suitable for various functions. A sample of heart tissue could not be expected to 'attract' other tissue into the form of a functioning heart by a winnowing process. There is, unsurprisingly, some unclarity as to whether the materialists think seed comes from

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21 Aristotle *GA* 1.18, 723a9ff.

22 As Aristotle reports of Anaxagoras: *GA* 1.17, 721b24ff; 1.18, 723a10; cf. *Nat. Puer.* 17.

23 ps-Plutarch *Ep.* 5.3.6=DK 68 A141. On this reading, the report that Democritus took the power of the seed to be *pneumatikê* (ps-Plutarch 5.4.2-3=DK 68 A 140) must be referring to its phenomenal appearance, not to its atomic composition.

tissues or from organs.[24] The materialists may be able to give some account of the growth and replication of homoiomerous masses by these means, but internally differentiated organs and organic individuals are another story.

In the end, even Democritus does not hold to the implausible idea that an accumulation of the right kinds of tissues in the right shape is sufficient for the functions of life: he introduces a unique kind of component, soul atoms.[25] For all the appeal of its consistency in using only material explanation, and its explanatory successes in accounting for some macroscopic effects by the motion of atoms, even the best of materialisms available in Aristotle's day fell woefully short in accounting for the capacities of living things. Scylla was a barren rock indeed.

Charybdis also had its shortcomings. Before Aristotle, some Presocratics attempted to account for the order in the cosmos by introducing basic explanatory principles like Love and Strife or Mind, said to be responsible for order and for the directedness of natural processes.[26] Neither of these pre-Aristotelian attempts to append goal-directed organizational principles onto a materialist account offer much resources for explaining the functioning of organisms or their reproduction. They are very general gestures toward explaining order and directionality, positing particular components of the cosmos with unanalysable teleological properties; few details survive as to how they would help account for the functions of organisms. Empedocles apparently drew on the notion that the uniting power of Love was once stronger in the world to explain why there is much less random combination than was once the case. He also seems to rely on the same principle to motivate something very different, however, which is the regular reproduction of kinds in the present age. Aristotle classifies these attempts at explanation as little more sophisticated than the anthromorphic deities of Hesiod.[27]

It is another obvious temptation to suppose that the goals or functions that feature in descriptions of organic processes are like the purposes of intentional agents. Natural processes might seem to aim at some goal because they are constructed to do so, perhaps by a beneficent Nature or a designer God, like Plato's cosmic Craftsman. But this only provides an account of the *ongoing* functioning of teleological processes if

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24 Aristotle *GA* 1.18, 722a16ff.

25 Aristotle *DA* 1.2-3; *PA* 2.7, 652b8.

26 Aristotle *Phys*. 3.4, 203b10-14; 8.1, 250b23-29; *DA* 1.2, 405a14. On Aristotle's understanding of these principles as teleological, see *Metaph*. 12.10, 1075b2-11.

27 *Metaph*. 1.4, 984b23-985b28.

it is assumed that the divine craftsman provides continuing direction to the natural world. Yet the whole movement of early ancient natural philosophy is precisely away from mythology's dependence on divine interventions and anthropomorphic forces. To return to these as explanation might well be taken as an admission of the failure of natural philosophy.

The continuing appeal of Aristotle's approach to explanation of the natural world is that he articulated the need for an account of the goal-directed operation of natural things, and does not rely on intentional design or direction to provide the explanation. Moreover, he respects the real strengths of the materialist explanations that were available. He did not seek to explain the *origin* of goal-directed forms in nature, but rather addressed the question of the ongoing regulation of apparently goal-directed effects, and did so without supposing that this is due to the intervention of some anthropomorphically conceived force or agent.

But did Aristotle genuinely recognize the desirability of occupying a 'middle ground', and regard teleological explanations as compatible with a complete materialist account of the components in which they are realized? Much controversy still surrounds his account of teleology: this next.

III The Controversy over Aristotle's View

A number of compelling accounts of Aristotle's natural philosophy in recent years have tried to show how his use of teleology is not grounded in a programmatic reference to *a priori* or Platonist ideas about the good, but are motivated by empirical concerns.[28] Aristotle recognized the power of materialist attempts to identify simple material principles underlying natural phenomena and to pursue material explanations, but he nonetheless insisted on the need for teleological explanations in addition. Some, like Nussbaum and Sorabji, have suggested that Aristotle allowed for the possibility of a necessitating material account, and that teleological explanations might play a merely pragmatic function.[29] Most scholars, however, suppose that teleological explanations are intended to play more than this merely epistemological role.

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28 In Solmsen's words, to 'reduce its metaphysical mortgage': Solmsen (1960, 92).

29 Nussbaum (1978), Sorabji (1980, 29-31). See Gotthelf (1997) for a helpful overview of alternative positions.

Some think that Aristotle's view of matter is deeply teleological from the start, whether because the matter of a complex cannot be identified independently, or because the properties of even the elements are given in teleological terms.[30] Nonetheless, several recent defenders of a strong reading of Aristotelian teleology resist reading Aristotle's theory as irredeemably teleological from the start: they emphasize the 'scientific' nature of its motivation and suggest that, for Aristotle, the appeal to teleology is justified only by the failures of materialism to account adequately for the observed features of the natural world. That is, he might have seen the desirability of pursuing a material account as far as possible, rather than too quickly positing unanalysably teleological properties or rendering the most fundamental levels of analysis irreducibly teleological. Whatever his final answer, Aristotle certainly seems to conceive the *possibility* that, say, rainfall could be accounted for by material necessity alone, and to ask whether the suitability of parts within the organism could be accounted for *like that*.[31]

On the one hand, Aristotle's insistence on providing material explanations for the workings of physiological processes seems to offer hope that his teleological explanations are not intended to preempt a useful analysis in terms of material components. On the other hand, his use of teleology seems at some points to preclude the possibility of a sufficient material account. Some interpreters read his functional definitions of organic parts, his insistence on the role of the Prime Mover,[32] or his use of notions like form, nature and potential, as evidence that Aristotle took any nonteleological, material account to be necessarily inadequate and incomplete, even on its own terms.

Interpreters differ on exactly what question needs to be settled to determine whether Aristotle thinks material accounts could be adequate on their own terms. Charles, for example, takes the disagreement to focus on whether a material account, by itself, could be necessitating or complete, that is, sufficient to bring about a given outcome.[33] Although

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30 Burnyeat (1992); Johnson (2005, 185).

31 *Physics* 2.8, 198b16ff. I shall not discuss this passage in more detail, although it has played a crucial role in the discussion of the scope of teleology in Aristotle: see, e.g., Judson (2005) for a recent study of the key secondary sources.

32 Kahn (1985).

33 Charles (1988). Code and Moravcsik (1992, 141-5), challenge Charles' framing of the question, on the grounds that talk of the 'sufficiency' of material accounts assumes an anachronistic modern notion of causation. Sorabji (1980) avoids this problem by talking of events as 'necessitated.' Although it is difficult to articulate precisely, it seems reasonable to ask, against the background of other ancient materialist accounts, about the necessity for teleological accounts: whether, as some

Gotthelf disagrees with this *answer* to the question, Charles and Gotthelf are in accord as to what the question *is*: whether Aristotle takes material explanation to suffice for each individual process.[34] Matthen, however, challenges this assessment of the key issue: in his view, the central question is not the adequacy of material change to effect *individual* outcomes; it is the insufficiency to explain the *regularity* of organic development that leads Aristotle to insist on teleology.[35] Cooper likewise argues that Aristotle's dissatisfaction with purely material accounts lies in the fact that species seem to him to be eternal, and the order in nature that is suitable for their persistence to be permanent.[36] Even if material processes could *produce* every outcome, there are still features of the natural world that materialism could not account for, i.e. the persisting *regularity* of the causal sequences that sustain species.[37]

This change of emphasis suggests that Aristotle's deepest commitment to teleology stems from the felt inadequacy of material accounts to show how not merely isolated outcomes, but *regular sequences* of coordinated changes, could come about.[38] If causal sequencing is the central issue, then it is perhaps no coincidence that mechanical devices might play a role in the discussion, since they provide the clearest case where a sequence of changes can be seen to follow, one from another, in a pre-arranged causal sequence. In two pivotal passages at the core of Aristotle's account of the definitive functions of organisms — animal self-motion and reproduction — Aristotle refers to the fact that the process in the organism is like the kind of regular causal sequencing found in 'automatic puppets.'[39] Although, as Devin Henry has recently

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commentators have put it, the necessity is purely epistemological, or whether it is metaphysical, i.e. based on some shortfall in material accounts considered on their own terms.

34 Charles (1988); Gotthelf (1976).

35 Matthen (1989). This is also the point emphasized in Hankinson (1998, 140, 145).

36 Cooper (1987, 244-50).

37 Cooper (1987, 250); (2004, 115-6).

38 Judson (2005) has challenged this change of emphasis, claiming that the materialists might claim simply that the environment supporting the regularity of organic life is *self-sustaining*, and that species are simply well-adapted to their environment. However, absent some developmental story, or some account of the mechanisms underlying the idea of a self-sustaining environment, these answers are not explanatory. Aristotle's demand for an account of this coordination between species and environment is, given his starting points, a valid one.

39 Aristotle *MA* 7, 701b2-17; *GA* 2.1, 734b9ff.

argued, the exact point made by the analogy in the two texts is not the same, in both cases Aristotle turns to craftsmanship to illustrate what is needed in organisms, i.e. some account of the production of regular causal sequences.[40] In *On the Motion of Animals*, the analogy illustrates the transitivity of efficient cause from one process to the next. In *On the Generation of Animals*, the point is a little different, which is to illustrate how it is possible for the male seed to govern subsequent processes, although it is not any longer in physical contact with the matter. Both the transmitted sequence of efficient causal processes and the formal-final nature of the seed are at work in explaining the regular sequence of changes in the organism.[41] Despite the differences, both cases draw an analogy to devices which show clear evidence of preprogrammed sequencing of changes. This is a prominent feature of the development of organisms, and one requiring explanation. The analogy to designed devices shows that such sequences can be produced to function without ongoing direction of a goal-directed kind, and yet without removing the need for some account of the design producing the sequences.

How could this be possible in organisms? Could material interactions alone produce anything like the regular sequences craftsmen produce by design? It cannot be coincidence or chance, Aristotle thinks: talk of material necessitation may suffice for isolated individual outcomes, but if the natural world requires regular sequences of causes, it is not enough to say that these come about by chance. Moreover, Aristotle does not believe that the materials used by the craftsmen could suffice to produce the requisite sequences of causes in organisms: in both cases where he talks of these sequences, the *material* responsible for the transmission of these sequences of motions turns out not to be ordinary terrestrial matter, but that peculiar substance, *pneuma*.[42] When he tells us

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40 The careful analysis in Henry (2005) shows that the two uses of the 'mechanical' analogy cannot be quite the same, as I had previously thought. However, in *GA* 2.1 and 2.5, Aristotle still regards the subsequent processes in the organism as forming a sequence of sorts, although all parts of the sequence have the form of the organism as final and formal cause, and the efficient causal sequence instigating them is insufficient alone. I disagree with Henry's suggestion that the mechanical device used as analogue in *GA* is necessarily different; rather, the use of the analogy in the latter case is limited. Whether or not the analogue superficially resembles a human being is irrelevant here: Preus (1970, 21).

41 When Henry (2005, 35), denies that 'the process leading from embryo to adult is a *causal* sequence,' in Aristotle's view, he seems to mean that it is not a merely efficient casual sequence. This is true, but does not undercut Aristotle's emphasis on the importance of such sequences. For Aristotle, of course, efficient cause is only part of the causal story.

42 Henry (2005, 6n10), rejects my emphasis on the role of *pneuma*, but he makes a

that this theoretical material, whose properties are largely those needed to explain the functioning of organisms, is analogous to the stuff of the stars and connected to the vital generative heat of the sun,[43] the prospects for a nonteleological account of *pneuma*'s capacities look bleak.

Aristotle's doubts about matter's ability to produce regular causal sequences is hardly surprising, even if he thought of a complete material account as a desideratum. The materialists' attempts to show how apparently useful combinations of parts could — occasionally — be produced by chance interactions of ordinary matter does not account for their regular occurrence, because chance conglomerations lack the regulative forms that can reliably reproduce themselves. There is no mechanism to move from an Empedoclean chaos of chance conglomerations to the orderly reproduction of functioning forms found in the present world. The materialist account of reproduction cannot show how matter can *set up* the regular sequence of changes that result in the production of new functioning organisms, without design. Suitable shapes might occasionally be produced by random processes, but not regular sequences of causes tending toward a given end.

But if we need teleological explanations because materialism cannot account for these sequences of coordinated changes, what underwrites those explanations? Does the natural world need to include goal-directed elements that are explanatorily basic, necessarily impervious to further analysis into nonteleological properties? If natural philosophy flourishes by pursuing the detailed study of the material structure of organisms and the hidden processes by which these patterns and functions are realized, too quick a resort to explanatorily basic teleological properties could be an impediment.

This can be seen in the work of some of Aristotle's successors. The Stoic ascription of all order to the presence of an intelligent directing substance infused throughout the cosmos leaves little role for nonteleological materialist explanations of particular organic processes. Galen, an influential advocate in late antiquity of the view that teleological properties go 'all the way down' and resist reduction to material properties, categorically rejects theories trying to account for the 'powers' of particular organs by the structural arrangements of the matter. Nature's beneficence, he argues, excludes the possibility that teleological results could operate by material means; he identifies the provision of useful

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comparable point that the male seed contains no mechanical parts: p. 32. The issue is that the material composition of the seed is such as to preclude further analysis of its capacities in nonteleological terms.

43 Aristotle *MA* 10, 703a9; *GA* 2.3, 736b29-37. See Berryman (2002c).

results with the creation of appropriate powers by qualitative change.[44] Plotinus, who also insists that nature's craftsmanship requires qualitative transformation of matter, likewise rejects the attempt of some of his contemporaries to draw on technology to understand the construction of the universe.[45] Technology works by merely reshaping matter, not qualitatively transforming it, and qualitative transformation is where idiosyncratic goal-directed forms, natures and powers enter. Simplicius, who acknowledges that the causal sequences in organisms happen without conscious awareness of the goals they aim at — as Aristotle told us, after all, it happens the way it does in automatic puppets — thinks this can only be explained by the causal influence of forms directing these sequences. Matter could not do this without intelligent direction.[46]

The dominant teleological thinking of late antiquity denied the possibility that sequences of material causes alone could regularly produce apparently goal-directed results. This understanding of teleological explanations as grounded in the existence of unanalysable powers or external intelligible causes forfeits the search for causally sufficient material accounts and 'veers towards Charybdis.' This is surely no accident: natural philosophers in Aristotle's wake had few resources for conceiving how teleological processes could be realized by nonteleological means. Having insisted on the necessity of asking what processes are *for*, there seems little grounds to insist on the search for a complete material account that will bring about exactly those ends. If purposes are built into the structure of the natural world, why think they can be realized by material processes whose operation is not goal-directed? Doesn't teleology suggest that matter itself must embody intentionality, be composed of unanalysably goal-directed powers? Given the difficulty of explaining how chance processes could produce not only suitable shapes, but complexes capable of causal sequences producing functional outcomes by material processes alone, the tendency toward Charbdyis is a natural one.

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44 Galen's commitment to irreducible powers — unanalysable and idiosyncratic to particular organs — leads him to criticize the attempts of some of his rivals to compare the fluid systems of the body to the systems of filters, siphons and pumps built by the mechanics of his day: Galen *Nat. Fac.* 2.3; see Berryman (2002b).

45 Plotinus, *Ennead* 3.8.2 and 5.9.6.

46 Simplicius, *in Phys.* 314.2-14. I thank Richard Sorabji and Devin Henry for drawing my attention to this passage.

IV The Role of Mechanistic Conceptions in Antiquity

It is against this background that I suggest that a 'mechanistic' approach to the investigation of the natural world be understood. It is important to emphasize that I am using the term in a specific way, to refer to the use of ideas and techniques derived from the study of the discipline called 'mechanics' in antiquity. Although Democritean atomism is often described as 'mechanistic' by twentieth century scholars, this usage is potentially misleading.[47] Rather, I use the term to draw attention to the role of mechanical theories and inventions in the causal thought of late antiquity.

I suggest that the comparison to the working artifacts available in antiquity could have offered a way to resolve the tension apparent in Aristotle's teleological thinking. His work raised fundamental problems about the nature of organisms and their relationship to their material components: it is metaphysically puzzling how a series of material interactions could reliably bring about a determinate result, and moreover one that is useful for the functioning of the organism. The few cases where regular causal sequences bring about desired outcomes by material processes do not go far towards suggesting how to achieve the kinds of functions found in organisms by purely material causal sequences.

But things changed. The centuries following Aristotle saw the development of the discipline of mechanics, which seems only to have existed in embryonic form in his day. It included the invention of increasingly complex devices, some of them capable of running 'by themselves' for a short period. There is of course no sense in which ancient devices work without external causal input; but this — as Aristotle emphasizes — is true of animal self-motion too.[48] Hero of Alexandria describes a device that shares with animals the ability to start moving in the absence of something pushing or pulling it.[49] Newly developed hydraulic or pneumatic devices — considered part of mechanics in ancient usage — were

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47 On this see Balme (1939); Berryman (2002b), (2003). There are similarities between atomism and the views of some later 'mechanical philosophers,' but applying the latter term to the ancient atomists too easily leads to confusion. It can be taken to imply that the ancient atomists share more in common with modern corpuscularians than is really the case, or that their motivations are the same. I explore this further in a book-length manuscript, in preparation.

48 Berryman (2002c).

49 *Aut*. 354-62.

used by some doctors as a basis for understanding the fluid dynamics of the body.[50]

What these constructed devices provided to later ancient natural philosophers was a way to conceive how a complex sequence of changes, resulting in a regular and apparently desirable outcome, could be produced by the rearrangement of the material alone, without need for goal-directed intervention in the operation of the sequence. The analogy is meant to show how, given an initial well-designed construction, a series of material changes can result in an apparently planned result. This does not, of course, answer all questions, especially how a well-designed construction pre-programmed in a certain way should come to be thus. Apparently the proponents of this approach simply suspended questions about the *origins* of suitable material complexes, or referred them vaguely to the gods. The question was not how complex structures come about, but whether they require ongoing intelligent direction. The analogy to mechanical devices could serve to focus attention on the material operation of processes within organisms. It does so without undermining the point of the question what given structures are for.

Only a few texts survive indicating that some natural philosophers in late antiquity looked to the devices of mechanics to understand the functioning of the natural world. Most considered this approach inadequate, if not outright theologically suspect, and it may be no accident that the work of its promoters has not survived. Still, such references as do survive indicate that the use of mechanical comparisons in late antiquity specifically focused on the ability of machines to illustrate a kind of causal process, i.e. the idea that, within a well-constructed complex, material processes alone could suffice reliably to bring about regular outcomes, via a preprogrammed sequence of changes. It is specifically the *sequence* of interconnected causal processes that are illustrated by the mechanical device. With the increasing sophistication of mechanical techniques, the plausibility of a 'mechanical conception' of organisms must surely have increased. While ancient technology falls short of offering analogues to every capacity of organisms, its startling success in mimicking self-motion may have been enough to inspire 'mechanistic conceptions' of organisms, in at least some quarters.

The role of such conceptions, l suggest, is to show how goal-directed functions could reliably be realized by material interactions, without assuming the explanatory burden of ascribing the *origins* of the complexes realizing those sequences to chance. Given the difficulties with the latter position, in the absence of some account whereby formal

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50 For discussion and further references, see Berryman (2002b).

properties could both arise by material processes and also be transmitted, there may be a legitimate role for an analogy that suspends the question of origins and focuses investigation on the material means of effecting regular causal sequences with an apparently goal-directed result. Perhaps the gods built us so that we run by ourselves. The fact that this is evidently possible in automata takes the wind out of the metaphysical argument for irreducibly teleological properties. Devices can be built without qualitative transformations of the material to introduce new natures or powers. So maybe organisms 'work like that.' Nothing requires that they do; but the existence of such devices weakens the argument that there *need* be irreducibly teleological powers as explanatory primitives.

This, I suggest, is how the term 'mechanistic' should best be used of antiquity. The ancient atomist programme seems to have been formulated independently of the discipline of mechanics or the study of devices; but with the development of the ancient field of mechanics, there seem to have been some who looked to it as a guide to investigating the natural world. The extent of the use of this conception seems to be rather limited — I know of only scattered references to such a conception, primarily those recorded by its critics — but it seems right to regard this as a distinct conception of the natural world. Caught between the implausibility of the materialist attempt to account for the emergence of functional forms and their regular reproduction, and the idea that gaps in a causal account needed to be filled in with explanatorily basic teleological components, it seems that some ancient thinkers turned to the mechanics for inspiration. Mechanical devices offered a way that material processes could produce goal-directed results: natural philosophers could draw analogy to working artifacts, and thus avoid the imputation that special powers or natures were needed to produce goal-directed results. For those who sought to occupy the kind of middle ground I have articulated, mechanics offered one way of invoking teleology without veering to the Charybdis of treating irreducible powers or unanalysable natures as efficient causes: a teleology without tears.[51]

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