

*Aristotelian Mechanistic Explanation**Monte Ransome Johnson*

In some influential histories of ancient philosophy, teleological explanation and mechanistic explanation are assumed to be directly opposed and mutually exclusive alternatives.¹ I contend that this assumption is deeply flawed, and distorts our understanding both of teleological and mechanistic explanation and of the history of mechanistic philosophy. To prove this point, I shall provide an overview of the first systematic treatise on mechanics, the short and neglected work *Mechanical Problems* (*Mech.*), written either by Aristotle or by a very early member of his school. I will argue that the work is thoroughly Aristotelian in methodology, and that taking it seriously can deepen our understanding of Aristotle's discussion of animal and human self-motion in the *Physics* (*Ph.*) and *On the Movement of Animals* (*MA*).

Because I call into question the assumption that teleological and mechanistic explanation are mutually exclusive, I begin by defining mechanistic

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¹ The following is representative of a very widespread assumption: "Whether . . . nature is such as to be completely describable without remainder in terms of purely mechanical laws of working, or whether rather nature demands to be understood in teleological terms, is the central question of Greek philosophical science" (Hankinson 1998: 6). An influential and accessible attempt to explain the whole history of science in terms of "the mechanization of the world picture" (and repudiation of Aristotelian modes of explanation) is Dijksterhuis 1950/1961: esp. 498; cf. 75–78. For further references, see Johnson 2005: 24–25 and n38. Sedley 2007 discusses "both sides of the ancient debate" (xvi) but presents the dichotomy more perspicuously in terms of the opposition between intelligent design creationism and atomism. Recently, De Groot 2014, who revives Aristotle's mechanics in a way that I find very congenial, has written: "the interaction of teleology and the mechanical thinking that I have highlighted is a topic of considerable interest, but the lines of development of these two types of natural explanation seem at the present reading independent of one another in important ways" (368; see further my review, Johnson 2015). The opposition between teleological and mechanistic explanation has already been called into question by von Staden 1997 (see 204 and n.89 on his summary of an argument for the opposition between teleology and mechanism), who focuses on the influence of Aristotelian biology on early Hellenistic medicine. See also 203–207, where Von Staden discusses several interesting mechanistic aspects of Aristotle's biology that I do not have space to discuss here.

explanation in a neutral way that will permit us to explore how Aristotelian teleological explanations could at the same time be mechanistic explanations. Thus the first part of this chapter provides some provisional definitions and applies them to some examples of explanation in ancient and modern science. The second part introduces *Mech.*, demonstrates the way in which it applies Aristotelian scientific method, and examines its compatibility with teleological explanations. In the third part, I offer a brief discussion of Aristotle's models of syllogistic explanation in *Posterior Analytics* (*APo.*) 2.11, and, in the fourth part, of biomechanical explanation in *Ph.*, *On the Soul* (*de An.*) and *MA*. I argue that these texts show that Aristotle envisioned a mechanistic explanation of human (and in general animal) self-motion. I then present a model of an integrated teleological and mechanistic explanation of a specific case of human self-motion based entirely on materials found in the various works of Aristotle that I have surveyed. I cast this explanation in syllogistic form so that its Aristotelian bona fides will be evident. The explanatory model that I construct can be deployed to probe the strengths and weaknesses of Aristotle's method of teleological-mechanistic explanation.

Teleological and Mechanistic Explanation

I begin with several provisional definitions that hopefully are relatively uncontroversial:

- (1) A *causal explanation* is a demonstration of the causes of something.
- (2) A *formal explanation* is a demonstration in which some form (or definition) is treated as the primary cause.
- (3) A *materialist explanation* is a demonstration in which some matter (or substratum) is treated as the primary cause.
- (4) A *teleological explanation* is a demonstration in which some good (or apparent good in the case of intentional action)² is treated as the primary cause.

The idea of a "mechanical" or "mechanistic" explanation has been understood in a bewildering variety of incompatible ways,³ but I will use the terms here in the following way:

² Aristotle holds that the good and the apparent good are interchangeable in teleological explanations of intentional action (*Ph.* 2.3.195a23–26; cf. *Top.* 146b36–147a11; *de An.* 433a27; *MA* 700b28–29; *Metaph.* 1072a27–28; *EN* 1113a16; *EE* 1227a20–31; *Rh.* 1369a2–4).

³ See the taxonomy of the term "mechanical" in Berryman 2009: 15–20. Berryman also doubts that there was "a theoretical understanding of the discipline of mechanics in the fourth century" (104).

- (5) A *mechanical explanation* is a demonstration proper to the science of mechanics (primarily of simple machines, such as the screw, lever, pulley, and pump).
- (6) A *mechanistic explanation* is a demonstration directly modelled on a mechanical explanation (for example, a biomechanical explanation).

For Aristotle, both teleological and materialist explanations involve necessity, but in different ways. Materialist explanations involve only absolute necessity (e.g. what is heated necessarily expands; what is cooled necessarily contracts). Teleological explanations involve hypothetical necessity as well (e.g. if temperature homeostasis is to be achieved, then internal organs must constantly be brought into contact with a cold body such as air). Teleological explanations involve *both* absolute and hypothetical necessity, but treat the end and its hypothetical implications as primary, holding the matter with its associated absolute necessities to be causes that cooperate to bring about the end.

As far as I can tell, none of the early or classical Greek philosophers sought to eliminate either teleological or materialist explanations. (Epicurus seems to have been the first philosopher to argue explicitly that materialist explanations displace the need for teleological explanations, and that we have additional, ethical reasons for rejecting such explanations as well.) Plato viewed what we now call materialist and teleological explanations as largely disconnected and accordingly confined them to separate parts of the discourse about intelligent design cosmology in the *Timaeus*. The theological diatribe of *Laws X* asserts the priority of intentional causes to material ones, but even here there is no indication that Plato thinks one kind of explanation can be eliminated in favour of the other. In the *Phaedo*, Socrates is made to argue that the materialist explanations of ancient Greek philosophers like Anaxagoras were woefully inadequate because they lacked reference to intentional causes. But, in response, Socrates does not try to *eliminate* materialist explanations, but rather to co-opt them, calling them things "without which the cause could not ever be a cause":

But from wondrous hope, my friend, I was quickly removed, when reading on I saw Anaxagoras neither using reason nor holding it to be a cause responsible for the ordering of the things, but holding responsible air and

because she too doubts that *Mech.* was a product of Aristotle or the first generation of his school. Cf. Carteron 1923/1975.

aether and water, and many other things and absurd ones. And to me it seemed to be a lot like if someone were saying that everything Socrates does he does with reason, but then in trying to say the causes of each of the things I do, he would say that I am sitting here now because of these things first: because my body consists of bones and nerves, and the bones are solid and separated from one another by joints, but the nerves are such as to contract and relax (surrounding the bones with the flesh and skin which hold them together); then because the bones are lifted in their own sockets, by softening and contracting, they make to bend somehow, as my limbs are now; and this is the cause of my sitting here now with bent legs. And again he would speak of other such causes concerning my conversing with you, holding responsible sounds and airs and hearing and myriad other such things, neglecting to say the true causes, that, since the Athenians considered it to be better to condemn me, that is why even I had considered it better to sit here and more just to remain and to pay the penalty which they would impose; since, by the dog, as I think, long ago these bones and these nerves, being moved by a belief about the best, would be among either the Megarians or Boeotians if I had not thought it more just and honorable to pay whatever penalty the city imposed rather than to flee and run away. But to call those things causes is surely absurd. But if someone were to say that without bones and nerves and such things, I would not be able to do what I believed, they would speak the truth; but to say that it is because of these things that I do those things which I do, even those things done with reason – but not because it was as the best – would be to speak at length of many things carelessly. For this would be a failure to distinguish between something that is a real cause, and that without which the cause could not ever be a cause. (98b7–99b4, emphasis added)

Consider three observations about this well-known and much-discussed passage. First, there is nothing mechanistic about the kind of explanation offered on behalf of Anaxagoras, and nothing in Plato's argument that is critical of mechanical or mechanistic explanation. According to my definitions, Plato is here criticizing Anaxagoras' *materialist explanation*, and calling for a *teleological explanation* of Socrates' behaviour. He wants to explain his remaining at rest in the prison cell (and not walking into exile) primarily by reference to "a belief about the best," that the best course of action is to pay the penalty (so manifesting the virtue of justice); but secondarily and as an adjunct by reference to the dispositions of his limbs and other body parts, along the lines of a materialist explanation. Second, then, Plato does not call for the exclusion or elimination of material causes; in fact he holds that such factors as the bones, sinews, air, and water are causes "without which the cause could not ever be a cause," meaning causes without which the primary cause, Socrates'

intention to pay the penalty, would not be able to function *as a cause*. Third, Plato here offers a model of teleological explanation of human behaviour according to which, for example, the motion of a man walking into exile would be explained by conjoining an account of his belief about the good with an account of the motion of his material parts: "these bones and these nerves, being moved by a belief about the best."

Plato's *Phaedo* thus contains a prototype of biomechanical explanation by hypothetical necessity: if such-and-such a good is to be realized (i.e. the good of going into exile), then bones and sinews will have to be moved this way and that; and it is, for example, the intention to obtain the good of escape into exile that somehow causes the bones and sinews to be moved. The movement of bones and sinews allows the good or apparent good to act as a cause – the primary cause – of the phenomenon of Socrates remaining in prison or walking off into exile. If there is to be an integral explanation of a phenomenon like Socrates walking into exile or remaining at rest in his prison cell, and not two isolated explanations with a mysterious relationship, one of intention and the other of bodily motions – then there needs to be a demonstration of how the intention and the movement of the body are causally related. The two possibilities considered in the *Phaedo* passage are: (1) the "Anaxagorean" account, according to which the bodily movements are the primary cause, the "efficient" cause of the intention (to put it in Aristotelian terms); and (2) the "Socratic" account, according to which the intention is the primary cause, the "final" cause of the bodily movements. The second precludes any account according to which certain movements of the body, for example in the brain (or "around the heart," in an Aristotelian cardiovascular account of the human sensory-motor system), are taken to be the cause – the primary cause – of the intention to walk into exile, so that non-intentional movements of the body should determine that Aristotle walked into exile, or that Socrates remained in his prison cell. Although Plato makes it clear which kind of explanation he would prefer ("these bones and these nerves, being moved by a belief about the best"), he portrays Socrates as abandoning the investigation at this point. But Aristotle took up the challenge,⁴ it would seem, and tried to show how

⁴ Thus I interpret *PA* 1.1.642a13–31 as a prose recapitulation of the *Phaedo* dialectic in which Democritus has been cast in place of Anaxagoras as the most important natural philosopher, and Socrates' abandonment of natural philosophy in favor of ethics and politics is presented as historical fact. In this context Aristotle says: "the cause of our predecessors not proceeding in this manner is that they did not have *the cause for the sake of which, i.e. the definition*. Democritus was the first to approach it, but he did not require it in his physical theory, instead he was brought to it by the fact of

intentional causes could be a cause of bodily motions, and thus function as the primary cause in the explanation of a human action such as walking. It is my contention that we should see this kind of explanation as mechanistic.

Before getting to that, however, let us consider a passage from an author who, in contrast to Aristotle, is widely held to have offered and advocated mechanistic explanation. Here is the Epicurean Lucretius' explanation of animal self-motion:

Now I will explain how it is that we can step forward when we wish, and move our limbs at will, and what the force is that propels the huge bulk of our body. I want you to take in what I say. I maintain, as I have maintained before, that first of all images of movement present themselves to the mind and impinge on it. Then comes the act of will: no one can begin to do anything until the mind has foreseen what it wills to do; and what it foresees is determined by the image. So, as soon as the mind stirs itself in such a way that it wishes to move forward, it acts on the spirit, whose force is disseminated throughout all the limbs and members of the body; and this is easily done, since mind and spirit are intimately connected. The spirit in its turn acts on the body, and so little by little a forward motion is imparted to the whole mass. Moreover, once in motion, the body becomes rarefied, and air, as one would expect of a substance that is always quick to move, penetrates the opened pores in an abundant stream and is thus distributed to every minute part of the body. So the body is driven forward by these two separate forces, *like a vessel propelled by the action of wind upon its sails*. There is nothing remarkable in the fact that such tiny particles can maneuver such a large body and turn about our whole bulk. Consider how the wind, though finely formed of subtle substance, drives before it a mighty vessel with mighty momentum, while a single hand guides the ship, no matter how swift its speed, and *a single helm steers it in any direction; consider, too, how a crane, with the help of pulleys and wheels, moves massive loads, hoisting them with slight effort*. (*Lucr.* IV. 877–906, tr. Smith, emphasis added)

In my understanding of the terms, Lucretius generally offers materialist explanations, but not mechanistic ones. Reference throughout the poem to kinds of matter, such as *primordia*, *materiem*, and *corpora* are certainly materialist, but not necessarily mechanistic. And where Lucretius speaks of the primordial bodies in terms of *semina* or *genitalia corpora*, we have

the matter itself. In the time of Socrates, a nearer approach was made, but the search for the things concerned with nature was given up, and the philosophers turned their attention towards the usefulness of virtue and the political" (642a24–31). Aristotle's solution is to integrate the intentional explanation (according to appropriate activities, or virtues and vices) with the Democritean account (according to the material necessities involved). The method of integration is hypothetical necessity.

something closer to a vitalistic or biomorphic explanation than a mechanistic one. Lucretius' comparison between the animal body and a sailing vessel is not necessarily mechanistic. But Lucretius does, in the end, offer a mechanistic explanation, because he models the mechanism of self-motion on actual machines: helm, crane, pulleys, and wheels. This certainly deserves to be called mechanistic; but since Lucretius nowhere offers an account of how the helm, crane, pulley, or wheel works, his explanation is not mechanical. One would have to add a mechanical explanation of the pulley, not a trivial piece of science, to the comparison between animal self-motion and the operation of a pulley in order to have a mechanical explanation in the strict sense.

For the sake of comparison, consider a recent (2011) explanation that has been offered for the phenomenon of yawning. A quotation from the study provides a good example of a mechanistic explanation:

The function of the paranasal sinuses has been a controversial subject since the time of Galen, with many different theories advanced about their biological significance. For one, the paranasal sinuses have been regarded as warmers of respiratory air, when in actuality these structures appear to function in cooling the blood. In fact, human paranasal sinuses have been shown to have higher volumes in individuals living in warmer climates, and thus may be considered radiators of the brain. The literature suggests that the transfer of cool venous blood from the paranasal sinuses to the dura mater may provide a *mechanism* for the convection process of cooling produced by the evaporation of mucus within human sinuses. In turn, the dura mater may transmit these temperature changes, initiated by the cool venous blood from the heat-dissipating surfaces of the sinuses, to the cerebrospinal fluid compartments. Furthermore, it has recently been demonstrated in cadaveric dissections that the thin bony posterior wall of the maxillary sinus serves as an origin for both medial and lateral pterygoid muscle segments, an anatomic finding that had been previously underappreciated in the literature. The present authors hypothesize that the thin posterior wall of the maxillary sinus may flex during yawning, operating *like a bellows pump*, actively ventilating the sinus system, and thus facilitating brain cooling. Such a powered ventilation system has not previously been described in humans, although an analogous system has been reported in birds.⁵

This explanation of yawning is *mechanistic* and the authors are justified in using the term "mechanism" because their explanation is modelled on the

⁵ Gallup and Hart 2011: 970, quoted with emphasis added.

mechanical explanation of a bellows pump. The explanation is no less mechanistic for the fact that it is at the same time teleological, in that the entire account is governed by the hypothetical function of yawning: cooling the brain. Notice however, that the explanation is not a *mechanical* explanation, because the authors do not themselves proceed to give an explanation of how the pump works. That is of course perfectly reasonable, given that the explanation of the pump is the object of another science, to wit the science of mechanics. If one wanted a deeper explanation of the phenomenon, one would have to learn a mechanical explanation of how the pump works, and then one could, in principle, assemble a mechanical explanation of yawning.

It is interesting to compare this recent piece of science to Aristotle's model of biological explanation in *Parts of Animals* I.I:

For example, one should demonstrate like this: *respiration is for the benefit of this, but this is also because of things of necessity*. Now necessity here means that if the thing will exist for the sake of something, then it is necessary to have these things exist; but at other times it means that things will exist like that and do so naturally. For the heat exits and returns, and the air enters, out of necessity; and this is indeed necessary. And so is the resistance of the internal heat in the cooling process: there is the entrance and exit of the internal air. In the foregoing we have an example of the method that we must adopt, and also an example of the kind of phenomena, the causes of which we have to investigate. (642a31–b4, emphasis added)

So far there is nothing mechanistic or mechanical in this explanation. It is a teleological one, which also involves material causes in a relation of hypothetical necessity to the end ("the benefit") of respiration. Respiration exists for the sake of cooling the internal organs, and this is achieved through certain qualities of matter: of hot and cold air. But in *On Respiration*, Aristotle gives a much fuller explanation of the same phenomenon, offering this time a mechanistic explanation:

Respiration takes place when the hot substance which is the seat of the nutritive principle increases. For it, like the rest of the body, requires nutrition, and more so than the members, for it is through it that they are nourished. But when it increases it necessarily causes the organ to rise. *This organ we must take to be constructed like the bellows in a smithy, for both heart and lungs conform pretty well to this shape*. Such a structure must be double, for the nutritive principle must be situated in the center of the natural force. Thus on increase of bulk expansion results, which necessarily causes the surrounding parts to rise. Now this can be seen to occur when people respire; they raise their chest because the motive principle of the

organ described resident within the chest causes an identical expansion of this organ. *When it dilates the outer air must rush in as into a bellows, and, being cold, by its chilling influence reduces by extinction the excess of the fire.* (Resp. 21 = Vit. 27.480a16–b1, tr. Ross, emphasis added; cf. Mir. 800a1–b5)

Again, I consider this a *mechanistic* explanation because it is modelled on a mechanical explanation of a bellows. Now Aristotle nowhere in the surviving works gives a mechanical explanation of the bellows,⁶ and so his explanation remains merely mechanistic. But the explanation is clearly no less mechanistic than the explanation of yawning cited above (in fact it strikingly resembles that explanation). Similarly, it is no more – but no less – mechanistic than Lucretius' explanation of animal self-motion. If we take Aristotle at his word that such an explanation of respiration is a paradigm of biological explanation, then it would seem that Aristotle is prepared to consider a mechanistic explanation of respiration to be a model of biological explanation. Since the explanation is at the same time a teleological one, I conclude here that teleological explanations do not necessarily exclude mechanistic explanations.

Mechanical Explanation

Much of the discussion about Aristotelian mechanics has tended to focus on the presence or absence of quantitative (proportional) laws of motion in the *Physics*.⁷ In the present context I set this issue aside and focus instead on geometrical demonstrations, since geometry is the mathematical science to which Aristotle holds mechanics to be subordinate when he mentions mechanics, along with optics, harmonics, and astronomy, as examples of mixed mathematical-physical science in *APo.* 1.13 and *Metaph.* 13.3. In *Ph.* 2.2, these are described as “the most natural of the mathematical sciences” (194a7–8; although mechanics is not explicitly mentioned in the *Physics* passage).⁸ The importance of geometry is also manifest in *Mechanical Problems*.

Although *Mech.* has long been included with the Aristotelian Corpus, and was a major factor in the revival of interest in mechanics in the

⁶ Nor should he necessarily have had to provide such an explanation, as the mechanism of such an action would have been regarded as self-explanatory or deducible by perusal of a blacksmith's forge.

⁷ In the important studies of Hardcastle 1914a and 1914b, Ross 1936 (introduction), Drabkin 1938, and Owen 1986, for example, one frequently encounters expressions like “proportionalities of natural motion,” “laws of motion,” “equations,” and “formulae” (in addition to actual equations offered experimentally to formulate Aristotle's laws of motion).

⁸ On the subordinate sciences in Aristotle's scientific method, see McKirahan 1978, Hankinson 2005, and Johnson 2015b.

fifteenth and sixteenth centuries,⁹ its status in modern times has been called into question. Although the present consensus is to assume that it is a work of an early follower of Aristotle, there does not seem to be any convincing reason to assume that it is not by Aristotle.¹⁰ Fortunately, nothing I argue for here requires the authentication of the author. I will proceed as if it were by Aristotle since the methodology of *Mech.* is self-consciously modelled on Aristotle's method in the *Analytics* and *Physics*. The actual author of the work makes no difference to the question of whether it is possible to conceive of (or develop) Aristotelian science as mechanistic.¹¹

Mechanics, like meteorological optics, is a mixed mathematical-physical science that offers to explain mechanical phenomena (such as levers, oars, and rudders) by relating them to geometrical principles. *Mech.* includes problems not just in human modification of nature, but also in completely natural processes devoid of any human intention. For example: Why do the pebbles on the seashore become round? (#15) Why are longer timbers weaker? (#16); Why do objects in eddies end up in the centre? (#35) Later we will consider a problem similar to #30 (Why do people rise from sitting putting feet back and shoulders forward?) because here we are offered a mechanical explanation of an aspect of human self-motion. But first it is necessary to understand the overall explanatory scheme of the *Mech.* The basic plan is laid out in its preface, according to which all mechanical phenomena are to be explained by deeper and deeper explanations ultimately traced back to a mathematical principle, that of the circle:¹²

There is nothing strange in the circle being the origin of any and every marvel. The phenomena observed in the balance can be referred to the circle, and those observed in the lever to the balance; while practically all the other phenomena of mechanical motion are connected with the lever. Furthermore, since no two points on one and the same radius travel with the same rapidity, but of two points that which is further from the center travels more quickly, many marvelous phenomena occur in the motions of

⁹ Laird 2000: 7–8; Hattab 2005: 99–130.

¹⁰ The most important considerations and a complete survey of the bibliography can be found in Berryman 2009: 97–114. I have also benefitted from an unpublished manuscript of McLaughlin, “The question of the authenticity of the *Mechanical Problems*.”

¹¹ As de Groot 2008: 45, has written: “Aristotle's own authorship is not necessary . . . to judge the kinship of the text to Aristotle's ideas and practice. It is a work of Aristotle's school and probably an early work.”

¹² De Groot 2008; Schiefsky 2009. My account of the method of *Mech.* has also benefitted from another unpublished manuscript by McLaughlin, “The program of Aristotle's mechanics and the balance with unequal arms.”

circles, which will be demonstrated in the following problems. (848a10–19, tr. Forster)

The method described here determines the very structure of the *Mech.*¹³ In the preface the circular motion principle is presented. We then have the following problems in the following order: Why are larger balances more accurate than smaller ones? (#1) Why does the balance supported from above but not below return to a level position? (#2) Why do small forces move great weight by means of a lever? (#3) Why do the rowers in the middle of the ship contribute more to its movement? (#4) Why does a small rudder have the ability to move the huge mass of a ship? (#5) The explanation of the rudder is referred to that of the lever, the lever to the asymmetrical balance, and the balance to the circular motion principle. A longer radius moving in a circle describes a greater arc than a shorter one with the same centre, but in the same amount of time. Aristotle describes this ability to move more at the endpoint of a longer radius as a capacity or power (*dunamis*) of the circle. The circle has the power to multiply or amplify motion and effect, and there exist various mechanical (and, it turns out, biomechanical) phenomena that bear this out, and they can all be explained by principles related to the circle. Aristotle seems to argue that for the longer radius there is more of the natural circular motion and less “forced” motion.¹⁴ Circular motion and its special properties have great cosmological significance for Aristotle, and he appeals to the nature of circular motion to explain not only the nature of the stars and planets, but also of animals and human beings.¹⁵ The circular motion principle directly explains what we now call third-class levers (which speed up the movement of a resisting weight with a small effort applied between a fulcrum and the resistance), but can be generalized (as Aristotle seems to do at 850a37–b2) into what is now taught in elementary mechanics textbooks as the law of the lever,¹⁶ although throughout the rest of *Mech.* the circular motion principle itself is applied, and not the law of the lever.¹⁷

For the sake of simplicity and uniformity, we may cast the circular motion principle into a syllogism (in Barbara, with universal affirmative propositions indicated by the symbol <a> which may be read “of every”;

¹³ Rose and Drake 1971.

¹⁴ Cf. *Cael.* 2.8, where Aristotle endeavours to explain how the sphere of fixed stars rotates so quickly despite being so much larger than the inferior spheres (289b34–290a5).

¹⁵ *Ph.* 4.14.223b19, 33, 5.4.227b18, 8.9.265a13–b16, *GC* 2.4.331a23–b4, 2.10.337a1–7, 2.11.338a4–b11. The responses to many of the problems in [Aristotle] *Pr.* XV (mathematical theory), XVI (inanimate things), and XVII (animate things) are suggestions concerning the nature of circles and circular motion.

¹⁶ Laird 2008: 175. ¹⁷ McLaughlin, “program of Aristotle’s mechanics,” p.4.

the extreme terms are italicized; the middle terms are in bold with conclusions indented):

- (1) *Greater movement* <a> **Farther endpoint from the centre**
- (2) **Farther endpoint from the centre** <a> *Longer radius*
- (3) *Greater movement* <a> *Longer radius*

The principle pertains to phenomena of greater movement, and the ultimate and "immediate" explanation for this is: being a farther endpoint on a radius of concentric circles. Now consider mechanical problem #1: Why are asymmetrical scales more accurate? We are trying to explain how a scale with one arm longer is capable, for example, of registering smaller differences in weight. If we cast the solution offered by Aristotle in the form of a syllogism, something like the following is the result:

- (3) *Greater movement* <a> **Longer radius**
- (4) **Longer radius** <a> *Asymmetrical scale*
- (5) *Greater movement* <a> *Asymmetrical scale*

A scale with one arm longer can register movement under influence of a smaller amount of weight and is hence more accurate; another way of putting this is that the movement at the endpoint of the longer arm is greater. The explanation for this is the circular motion principle. The two syllogisms can be linked, with the conclusion of the circular motion principle serving as the major premise of the syllogism linking that principle to the phenomenon of the asymmetrical scale, the explanandum. The circular motion principle serves as the *reason why* an equal weight on the endpoint of the arm of an asymmetrical scale moves more than the same weight on the endpoint of a scale with equal arms. We deepen our knowledge of the scale by referring to the circular motion principle. Thus the explanation of the scale can be represented in a unified 5-proposition syllogism.

But this can be expanded. Just as we can deepen our knowledge of mechanical phenomena like balances, so can we widen the scope of the science to explain other phenomena, such as the lever, as in problem #3: Why can small forces move great weights by means of a lever? Consider the following:

- (5) *Greater movement* <a> **Asymmetrical scale**
- (6) **Asymmetrical scale** <a> *Lever*
- (7) *Greater movement* <a> *Lever*

A lever just is an asymmetrical scale, for they have the same form, and so the explanation of one refers to that of the other. And noticing this form in

still other things, we may widen our knowledge still further, for example to the rudder, as in problem #5: How is a small rudder able to move the huge mass of a ship? The next syllogism elucidates:

(7) *Greater Movement* <a> *Lever*

(8) *Lever* <a> *Rudder*

(9) *Greater movement* <a> *Rudder*

We can look at these syllogisms in either of two directions. Either we head inwards towards the principle (1)–(2)–(3), deepening our knowledge of various phenomena (scales, levers, rudders, etc.) by apprehending the geometrical principle at work; or, we can head outwards towards the phenomena of (7) and (9), extending our knowledge based on the geometry of the circle by applying it to more diverse observed phenomena that all have the same form.

Perhaps the most straightforward way to put it is that observed facts about the rudder, lever, scale, etc. are explained by referring them to mechanical and geometrical principles. Earlier philosophers had proposed tracing the motions of natural bodies to geometrical principles; for example, Plato to the atomic triangles of the *Timaeus*, or Democritus to the variously shaped and arranged atoms. There is no doubt that they envisioned the possibility of tracing explanations of related phenomena, including animal motion, to such principles as well. Such explanations should not, however, be considered “mechanical” explanations, except in a loose way of talking that philosophers sometimes employ to describe explanations referring to material and moving causes. But since the explanations we have just been considering are parts of an elaborately conceived science of mechanics, written in the first complete and systematic treatise devoted to the science of mechanics (a work with a demonstrable direct influence on the mechanical philosophies of Galileo, Gassendi, Hobbes, and Descartes, for example), it would be reasonable to label these, in the strongest technical sense, mechanical.

Syllogistic Explanation

In *APo.* 2.11, Aristotle describes how scientific explanations in general are to be represented as syllogisms in which the middle term indicates the cause of the phenomenon to be explained, according to one of four kinds of cause. The first example he gives is a formal explanation of why the angle in the semicircle is always a right angle (94a24–34):

- (1) *Right angle* <a> **Half of two right angles**
- (2) **Half of two right angles** <a> *Angle in the semicircle*
- (3) *Right angle* <a> *Angle in the semicircle*

In this explanation, the definition of a right angle is given as the cause (and thus middle term) for the fact that every angle in the semicircle is a right angle. The definition itself cannot be demonstrated, but is treated as an axiom grasped by intuition (*nous*). I have earlier argued (Johnson 2009) that a similar formal explanation is offered by Aristotle of a natural phenomenon in the *Meteorology*. There, Aristotle explains why the meteorological halo always appears as a complete circle:

- (1) *Circle* <a> **Figure contained by one line such that all the straight lines falling upon it from one point among those lying within the figure equal one another**
- (2) **Figure contained by one line, etc.** <a> *Light deviated to an observer at a constant angle from a luminous body*
- (3) *Circle* <a> **Light deviated to an observer at a constant angle, etc.**
- (4) **Light deviated to an observer at a constant angle, etc.** <a> *Halo shape appearing in the clouds between the observer and the moon*
- (5) *Circle* <a> *Halo shape appearing in the clouds between the observer and the moon*

The explanation consists of two syllogisms. In the first, the major premise is the definition of the circle, and the minor premise asserts that this definition applies to appearances caused by the deviation (refraction, actually) of light at a constant angle. Aristotle asserted that the optical illusion of a halo appearing around a star is caused by the uniform deviation of light from (or “sight to”) a star (sun, moon, planet, etc.) in a cloud consisting of “tiny and uniform” particles (hexagonal ice crystals, actually). The same explanation applies to lunar, solar, and stellar halos, and so the second syllogism can be modified so as to produce an explanation of each of these phenomena. We have already seen a similar kind of explanation at work in *Mech*. The circular motion principle is the ultimate explanation for a diverse set of phenomena, including scales, levers, and rudders.

One striking thing about the other explanatory examples in *Apo*. 2.11 is that some of them are teleological explanations of individual human intentional actions, and one is even of a particular historical event. For instance, in his example of the cause “what initiated motion” (94a36–b7):

- (1) *War* <a> **Launching an attack**
- (2) **Launching an attack** <a> *Athenians*
- (3) *War* <a> *Athenians*

The example is striking because it offers to explain a particular and unique historical event, the Persian War. Aristotle seems to have adapted Herodotus' explanation (V.97.3) to his own method: it was the launching of an attack on Sardis with the Ionians that caused the Persian war, and thus launching an attack has to be positioned as a middle term. Next, consider the "Pythagorean" explanation of thunder, which Aristotle entertains in addition to its formal definition (94b32–34 = DK 58C1):

- (1) *Noise in the clouds* <a> **Fire extinguishment**
- (2) **Fire extinguishment** <a> *Good of terrorizing Hades*
- (3) *Noise in the clouds* <a> **Good of terrorizing Hades**
- (4) **Good of terrorizing Hades** <a> *Thunder*
- (5) *Noise in the clouds* <a> *Thunder*

In this way, Aristotle can offer an explanation of thunder that integrates a formal definition of thunder ("fire extinguishment") with a teleological explanation (the good of terrorizing Hades – or at least the good of terrorizing Hades that appears good to Zeus, or Pythagoras). A less bizarre (although more contested) example is Aristotle's explanation of why a health-conscious person (call him "Aristotle") takes a walk after dinner (94b8–23):

- (1) *Walk after dinner* <a> **Digesting the food well**
- (2) **Digesting the food well** <a> *Good of health*
- (3) *Walk after dinner* <a> *Good of health*
- (4) *Good of health* <a> *Aristotle*
- (5) *Walk after dinner* <a> *Aristotle*

The explanation includes a material (*qua* physiological) explanation of why walking after dinner is healthy (because it aids digestion by making the food not stick to the surface of the stomach). But it also includes the teleological explanation of the good of being healthy. I have presented these in an integrated explanation. Thus the reason Aristotle takes a walk after dinner is the apparent good of health, but the reason why it is healthy to walk after dinner (and the cause that Aristotle has in mind if he has scientific understanding of what he is doing) is that walking makes the food not adhere to the surface of the stomach (i.e. digest well). Although in this example Aristotle provides a material explanation, not a mechanistic one, in my view many mechanical and mechanistic explanations follow this paradigm, and thus can be seen as types of materialist explanations, which are, of course, generally incomplete unless integrated with a teleological one.

One could widen the extension of this explanation to include anyone else (such as Callias) who is health-conscious and so takes a postprandial

constitutional. The example indicates, despite its many obscurities, that Aristotle intends his scheme of causal explanation to be able to explain *individual* human actions. And there are several other places in which Aristotle, perhaps not surprisingly for the founder of the Peripatetic School, uses the example of an individual walking in discussing a point of method.¹⁸

This is important for my purposes, because I am arguing that an Aristotelian can provide a teleological explanation of particular human actions, such as the paradigmatic ones of Socrates remaining at rest in his prison cell, or Aristotle walking into exile in Chalcis, and the examples in *APo.* 2.11 show, if nothing else, that Aristotle allows for such explanations. But this much is also clear from *MA* 7:

But how is it that thought is sometimes followed by action, sometimes not; sometimes by movement, sometimes not? What happens seems parallel to the case of thinking and inferring about the immovable objects. There the end is the truth seen (for, when one thinks the two propositions, one thinks and puts together the conclusion). But here the two propositions result in a conclusion which is an action.

For example: (1) whenever one thinks that every man should walk, and that one is a man oneself, straightaway one walks; or that, (2) in the case no man should walk: straightaway one remains at rest. And one so acts in the two cases provided that there is nothing to compel or to prevent.

Again, (3) I ought to create a good, a house is a good: straightaway he makes a house. (4) I need a covering, a coat is a covering: I need a coat. (5) What I need I ought to make, I need a coat: I make a coat. And the conclusion "I must make a coat" is an action, and the action goes back to a starting point. If there is to be a coat, there must first be this, and if this then that – and straightaway he does that.

Now that the action is the conclusion is clear. But the premises of action are of two kinds, of the good and of the possible. And as sometimes happens in dialectical questioning, so here the intellect does not stop and consider at all the one proposition (the obvious one). For example, if walking is good for man, one does not dwell on the proposition "I am a man". And so what we do without reflection, we do quickly.

For when a man is actually using perception or imagination or thought in relation to that for the sake of which, what he desires he does at once. For the actualizing of the desire is a substitute for inquiry or thinking. (6) I want to drink, says appetite; this is a drink, says sense or imagination or thought: straightaway I drink.

In this way animals are impelled to move and to act, and desire is the last cause of movement, and desire arises through perception or through imagination

¹⁸ E.g., *SE* 172a8–9; *Ph.* 194b32–35, 197b22–25; *MA* 701a7–15; *Metaph.* 1013a33–35.

and thought. And things that desire to act make and act sometimes from appetite or impulse and sometimes from wish. (701a7–701b1, tr. Farquharson, adapted, emphasis added; numbers added in parentheses for ease of reference)

It has to be admitted at the outset that there are grave problems with these examples. “Syllogisms” (1), (2), and (3) all seem to be invalid because the premises include “ought” statements (e.g. “Every man ought to walk”) combined with descriptions (“I am a man”), but the conclusion is an action (“I walk”). Syllogism (4) can at best explain why I need a coat (because I need a covering), but cannot explain why I make a coat, as (5) pretends to do, because, again, syllogism (5) inexplicably moves from an “ought” statement and a description to an action. Again, (6) seems to be invalid because the premises consist of a mental state (“I want to drink”) and a description of perception (“This is a drink”), but the conclusion is an action (“I drink”). What can be learned from these highly problematic examples? At least this: that Aristotle envisioned syllogistic and causal explanations of particular human actions – such as walking or remaining at rest – in the scientific work devoted on the motion of animals, something that is also suggested in his general treatment of scientific explanation in *Posterior Analytics* 2.11. And, as I will show in due course, he intends these explanations to be integrated with a biomechanical and mechanistic explanation.

Biomechanical Explanation

In the methodological opening chapter of *de An.* 1.1, Aristotle describes how two different kinds of cause are to be integrated in the explanation of anger:

It is clear that the affections are accounts in matter, and so are their definitions, for example: anger is *a certain movement of such a body or part (or capacity for this) for the sake of something.* And it is for these very reasons that the theory of psychology is a natural science, either all of it or specifically this part. But a natural scientist and a dialectician would define each of the affections differently, for example: what is anger? The dialectician might define it as *the desire for revenge or something like that,* but the natural scientist as *the presence of blood and heat around the heart.* (403a25–b1, emphasis added)

Aristotle cannot here be accepting two different and isolated explanations of anger, one intentionalistic (“dialectical”) and the other materialistic (“natural scientific”), and hold that the two are only accidentally conjoined

in the phenomenon of anger. How then are the accounts related? Aristotle must be arguing that there should be an intentionalistic explanation ("desire for revenge") related to material causes ("blood boiling") by hypothetical necessity. Thus the boiling of the blood must be understood to be *for the sake of* the desire for revenge. And this is precisely what he does say. That the physiological aspects of anger are understood by Aristotle to be for the sake of something is confirmed by the elaborate arguments in *Rhetoric* 2.2–4 that anger is *always* for the sake of something:

it must always be attended by a certain pleasure, that which arises from the expectation of revenge. For it is pleasant to think that you will attain what you aim at, and nobody aims at what he cannot attain . . . it is also attended by a certain pleasure because the thoughts dwell upon the act of vengeance, and the images then called up cause pleasure, like images called up in dreams. (1378b1–9, tr. Roberts; cf. 1379a10–11, 1382a7–10)

Anger therefore is boiling of the blood near the heart for the sake of something, namely revenge, which either is a good or appears as a good (for which reason it is also accompanied by pleasure). But this paradigm of teleological explanation in *de An.* 1.1, in which the bodily movements are taken to be for the sake of some good (or apparent good), is in perfect agreement with the paradigm explanation of respiration in *PA* 1.1, discussed above, according to which air is heated and cooled *for the sake of* cooling the internal organs. These are both paradigms of hypothetical necessity.

In the account of self-motion in *de An.* 3.10, Aristotle states that, in addition to intentional causes like desire, reason, and deliberation, part of the explanation is material:

The instrument which appetite employs to produce movement is bodily: hence the examination of it falls within the province of the functions common to body and soul. To state the matter summarily at present, that which is the instrument in the production of movement is to be found where a beginning and an end coincide as e.g. in a ball and socket joint . . . for everything is moved by pushing and pulling. Hence *just as in the case of a wheel, so here there must be a point which remains at rest, and from that point the movement must originate.* (433b19–27, emphasis added)

Aristotle requires both an intentionalistic or psychological account (according to appetite) and a materialistic ("bodily") account in the explanation of animal or human self-motion. But how are they to be integrated? The answer, following the examples of *de An.* 1.1 and *PA* 1.1, is that the material causes are going to be understood as instrumental for the sake of

the intentional causes, so that the intentional causes hypothetically necessitate the pushing and pulling of body parts, and the above passage puts this in such a way that amounts to a mechanistic account.

In *Ph.* 8.4, Aristotle compares animal self-motion to a sailing vessel (as we saw that Lucretius did as well): “It would seem that in animals, just as in ships and in things not naturally constituted, that which causes motion is separate from that which suffers motion, and that in this way the animal as a whole causes its own motion” (254b29). He later mentions the lever as an example of a mechanism of unnatural motion (255a22). Later, Aristotle explicitly describes the mechanism of natural self-motion as leverage:

Moreover in all these self-moving things the first mover and cause of their self-motion is itself moved by itself, though in an incidental sense: for the body changes its place, so that that which is in the body changes its place also and *moves itself by means of the lever*. (*Ph.* 8.6.259b16–20, emphasis added)

It is crucially important to figure out what Aristotle means by “moves itself by means of the lever” (*tei mochleiai kinoun heauto*) here. The answer is to be found in *MA*, which opens with the following observation:

If one of the parts of an animal be moved, another must be at rest, and this is the purpose of their joints; animals use joints like a center, and the whole member, in which the joint is, becomes both one and two, both straight and bent, changing potentially and actually by reason of the joint. And when it is bending and being moved one of the points in the joint is moved and one is at rest, just as if on a diameter AD were at rest, and B were moved, and AC were generated. (698a18–24)

There is a direct connection between this description and one in *Mech.*, as commentators have long noted.¹⁹ Aristotle’s conception is that the limb moves as a lever: the fulcrum (A) is a joint (e.g. an elbow or knee) located along limb (BAD), and the motion of the extremity (e.g. a hand or foot) from (B) to (C) along arc BC is a circular motion, just as in the rudder, lever and asymmetrical scale of the *Mechanics*. (In fact, the human arm is a third-class lever – which explains how it is possible to flex your arm so quickly. By contracting your biceps about an inch, you are able to move your hand over an 18 inch arc with elbow as fulcrum.) Edmund Hussey has summarized the general idea of Aristotle’s account of animal motion: “Animal movement is like rowing: the animal has limbs equivalent to oars which it uses to lever through the resisting medium, or gets the same effect by bending sharply (*MA* 1–2; *IA* 3.705a3–19). For each ‘oar’ there is

¹⁹ De Groot 2008: 54–55.

a fixed 'point' during the movement, corresponding to the fulcrum of the lever."²⁰ If this is right, then Aristotle's explanation of animal motion is a mechanistic one, because it explains animal motion on the model of an explanation of an oar, which is a machine for which a mechanical explanation is offered in *Mech.* by tracing it to the lever, and ultimately to the circular motion principle.

Later in *MA* 7, in the same chapter in which Aristotle mentioned practical syllogisms to explain human actions like walking and remaining at rest, Aristotle offers a psychological and biomechanical explanation of animal motion.

The movements of animals may be compared with those of automatic puppets, which are set going on the occasion of a tiny movement (the strings are released, and the pegs strike against one another); or with the toy wagon (for the child mounts on it and moves it straight forward, and yet it is moved in a circle owing to its wheels being of uneven diameter – the smaller acts like a center on the same principle as the cylinders). Animals have parts of a similar kind, their organs, the sinewy tendons to wit and the bones; the bones are like the pegs and the iron; the tendons are like the strings; for when these are slackened or released movement begins . . . In an animal the same part has the power of becoming now larger and now smaller, and changing its form, as the parts increase by warmth and again contract by cold and change their quality. This change of quality is caused by imaginations and sensations and by ideas. Sensations are obviously a form of change of quality, and imagination and thinking have the same power as the objects. For in a measure the form conceived be it of hot or cold or pleasant or fearful is like what the actual objects would be, and so we shudder and are frightened merely by thinking. Now all these affections are actually changes of quality, and with those changes some parts of the body enlarge, others grow smaller. And it is not hard to see that *a small change occurring at the center makes great and numerous changes at the circumference, just as by shifting the rudder a hair's breadth you get a wide deviation at the prow.* And further, when by reason of heat or cold or some kindred affection a change is set up in the region of the heart, even in an imperceptibly small part of the heart, it produces a vast difference in the body – blushing, let us say, or turning white, and trembling and shivers and their opposites. (701b1–32, tr. Farquharson, emphasis added)

Thus Aristotle offers a mechanistic explanation of animal and human self-motion, because the explanation is modelled on mechanical phenomena: the rudder and the lever. But since the author of *Mech.* can also offer

²⁰ Hussey 1991: 232.

a mechanical explanation of the rudder, it appears that an Aristotelian can offer not only a mechanistic explanation of animal self-motion, but also a fully mechanical one. In what immediately follows from *MA* (now divided into chapter 8, although the argument is continuous), Aristotle links psychological states like boldness, fear, and erotic arousal, via pleasure and pain, to heating and cooling internal body parts, and by extension to the movement of the limbs:

But, again, as has been explained, the object we pursue or avoid in the field of action is the origin of movement, and upon the thought and imagination of this there necessarily follows a heating or chilling. For what is painful we avoid, what is pleasing we pursue, and anything painful or pleasing is generally speaking accompanied by chilling and heating (but we do not notice this when it happens in a small part). One may see this by considering the affections. Over-boldness, fears, erotic motions, and the rest of the corporeal affections, pleasant and painful, are all accompanied by heating and chilling, some in a particular member, others in the body generally. (701b33–702a5, tr. Farquharson, adapted, emphasis added; cf. *Juv.* 26, 479b22–26)

In the final part of this chapter, I will attempt an integrated teleological and mechanistic explanation of human self-motion modelled on this passage. But before doing so, I need to show how the psychological account of the passions and its biomechanical implications can be represented syllogistically. We could use the examples of fear or boldness from the above passage from *MA*, but let us return to the example of anger in *de An.* I.I. First of all, I take it that what Aristotle is explaining is the behaviour of an angry person: why and how they strike out or lash out at the one with whom they are angry for the sake of revenge. That the person who is angry moves or at least desires to move is implicit in the “dialectical” definition of anger in terms of revenge; Aristotle does not imagine a person remaining at rest stewing in anger, but rather someone like Achilles, actively raging with anger, motivated to war. Again, Aristotle stresses that anger is for the sake of something, and aims at a definite end, and this is why it is accompanied by pleasure. Thus I will assume that some kind of self-motion of an angry person such as Achilles’ limbs (e.g. fist or foot) is the ultimate phenomenon to be explained:

- (1) *Greater movement* <a> *Good of revenge*
- (2) *Good of revenge* <a> *Achilles*
- (3) *Greater movement* <a> *Achilles*

Thus the apparent good of revenge is the cause or reason why the person moved (e.g. lashed out with punches). But now suppose we add the

following mechanistic explanation (built from the materials mentioned in *MA* 7) in conjunction with this teleological syllogism in order to explain *how* the intentional state manages to affect the motion of the limbs:

- (1) Greater movement <a> **Rudder**
- (2) **Rudder** <a> Enlargement at the heart
 - (3) Greater movement <a> **Enlargement at the heart**
 - (4) **Enlargement** <a> Heating of blood around the heart
 - (5) Greater movement <a> **Heating of blood at the heart**
 - (6) **Heating of blood** <a> Pleasure
 - (7) Greater movement <a> **Pleasure**
 - (8) **Pleasure** <a> Good of revenge
 - (9) Greater movement <a> **Good of revenge**
 - (10) **Good of revenge** <a> Achilles
 - (11) Greater movement <a> Achilles

Notice that one does not read the explanation in the order of (1) to (11): not every operation of a lever results in an enlargement at the heart, or is for the sake of revenge, of course. Rather one reads this explanation in the reverse direction, from (11) back to (1): the final and ultimate moving cause of the angry person's motion was the appearance of the good of revenge, which is accompanied pleasure, causing heating of the blood around the heart, enlarging that organ so that it acts as a rudder. At this point one may supply the mechanical explanation of how the rudder can cause greater motion, tracing the explanation back to the circular motion principle. The causes such as heat and blood and the heart are cooperating or contributing causes that allow the good to act as a cause, and "without which the cause could not ever be a cause." Thus the end of anger is revenge and the mechanism of self-motion this entails is leverage, exactly as Aristotle suggested in *Ph.* 8, since the rudder of *MA* 7–8 can be referred to the lever of *Mech.* Notice that this explanation cannot explain why one moves one's feet as opposed to fists, or why one takes a left turn instead of a right. This kind of explanation only shows how the intentional state can cause some kind of increased motion in the body.

Anger is the excess of a virtue called *praotês* (*EN* 4.5.1125b26). And in the beginning of chapter 8 in *MA*, Aristotle indicates that the kind of explanation he has been describing will apply to "over-boldness, fears, erotic motions and the rest of the corporeal affections, pleasant and painful, [which] are all accompanied by heating and chilling, some in a particular member, others in the body generally." The overall vision connects the virtues with the passions, the passions with pleasure and pain,

and pleasure and pain to biomechanical functions. This helps us understand why Aristotle in the *Ethics* lays such great stress on the study of pleasure and pain, and is so concerned to define the moral virtues and vices with respect to these mental states.²¹ In *MA* 8, Aristotle seems to have in mind an explanation of human action in the domain of the virtue courage, which lies at a mean relative to excesses of boldness (*tharrê*) and fears (*phoboi*). Thus a mechanistic explanation could be given of vicious action and, *mutatis mutandis*, of virtuous (e.g. courageous) action. A hint at the domain of temperance is Aristotle's mention of "erotic motions" (*aphrodisiasmoi*).²² Since, as we have seen, pleasure and pain can be connected with heating and chilling, and thereby to expansion and contraction, a good can be linked to a mechanistic explanation of an animal or human movement. In this way a path is open to linking ethical definitions to the teleological explanations that can be integrated with mechanistic ones via an account of the heating and cooling effects of pleasure and pain on the heart. Such explanations can then be combined with a mechanical explanation of mechanistic phenomena such as pumps, pulleys, rudders, levers, and scales, resulting in a complete and integral teleological-mechanistic explanation of human behaviour.

As an example, I offer a syllogistic explanation of Aristotle walking into exile (to Chalcis, where he died). The conclusion at proposition (21) below is the phenomenon to be explained: Aristotle walking into exile ("greater movement of Aristotle"). Propositions (16) to (20) are theorems of moral psychology that a person possessing a certain intention (such as a desire to avoid letting the Athenians sin twice against philosophy), will experience pleasure (or pain) at the intention of walking away from the Lyceum into exile. Pleasure causes heating in the region of the heart, as we have just seen in the discussion of anger. Propositions (10) to (15) are biomechanical theorems that explain how heating and cooling affect a rudder-like mechanism in the region of the heart, in this case by expanding it to a longer lever. Propositions (4) to (9) are mechanical theorems that explain how an enlarged rudder is capable of amplifying motion. Propositions (1) to (3) are the circular motion principle.

²¹ *EN* 2.3.1104b11–13, 7.12.1152b1–3, 10.1.1172a20–21.

²² See *Pr.* IV 23: "Why does erection and growth of the penis occur? Is it for two reasons: because through weight being added behind the testicles, it is raised (for the testicles become a fulcrum), and because the passages become full of *pneuma*? Or does the bulk become greater as the moisture increases and changes position, or from the formation of moisture. Now very large things are less easily raised because the weight is farther away from the fulcrum" (879a17–21, tr. Mayhew). It is fascinating that this hypothetical account of the erection is mechanical (and not only mechanistic).

The circular motion principle thus leads the explanation of how (not why) it is that a person having certain beliefs about the good could, by having their bones and sinews affected, move or walk into exile:

- (1) *Greater movement* <a> **Farther endpoint**
- (2) *Farther endpoint* <a> *Longer radius*
 - (3) *Greater movement* <a> **Longer radius**
 - (4) **Longer radius** <a> *Asymmetrical scale*
 - (5) *Greater movement* <a> **Asymmetrical scale**
 - (6) **Asymmetrical scale** <a> *Lever*
 - (7) *Greater movement* <a> **Lever**
 - (8) **Lever** <a> *Rudder*
 - (9) *Greater movement* <a> **Rudder**

Next, this mechanical principle and these theorems can be linked to the following biomechanical ones:

- (10) **Rudder** <a> *Enlargement at the heart*
 - (11) *Greater movement* <a> **Enlargement at the heart**
 - (12) **Enlargement at the heart** <a> *Heating at the heart*
 - (13) *Greater movement* <a> **Heating at the heart**
 - (14) **Heating at the heart** <a> *Pleasure*
 - (15) *Greater movement* <a> **Pleasure**

The result is that it is possible to give a deeper explanation of the biomechanical theorems by reference to the mechanical ones, and ultimately the circular motion principle. And those biomechanical theorems can be linked to intentionalistic and teleological ends in the following way:

- (16) **Pleasure** <a> *Going into exile*
 - (17) *Greater movement* <a> **Going into exile**
 - (18) **Going into exile** <a> *Good of disallowing the Athenians to sin twice*
 - (19) *Greater movement* <a> **Good of disallowing the Athenians to sin twice**
 - (20) **Good of disallowing the Athenians to sin twice** <a> *Aristotle*
 - (21) *Greater movement* <a> *Aristotle*

The result is that the explanation of action can integrate intentional causes with biomechanical and mechanical ones. This exercise adapts, in Aristotelian logic and terminology, the model of action described by Socrates in the *Phaedo*: “these bones and these nerves, being moved by a belief about the best, would be among the Megarians or Boeotians if I had not thought it to be more just and honourable.” *Mutatis mutandis*, one

could in theory explain Socrates' remaining at rest in his prison cell. The biomechanical and mechanical theorems and principles explain the co-causes of Aristotle's action – they allow the apparent good and thus the intention to act as a cause, the primary cause, and without them that primary cause “could not ever be a cause.” It is a remarkable fact, and one in need of explanation, how such an apparently insubstantial thing as the appearance of a good could cause something as substantial as moving the whole body. It is not enough to say that the body functions just like puppets or automata, being governed by mechanical process. One thing that needs explanation is apparent disproportion involved: how with a relatively small effort (such as pulling a string or removing a peg) one can possibly bring about such a considerable change (apparent self-motion); this is explained by mechanisms like leverage, and thus ultimately by mechanical science, which possesses an explanation of how, with a relatively small force, a very heavy load may be lifted using a lever; so in the case of animal or human self-motion, a very slight change in the region of the heart (or brain, if you prefer) can cause a very great change (human self-motion). Aristotle sees that there is a means of explaining this mechanistically.

Conclusion

The complete explanation of such an action (both the intentionalistic and the mechanistic aspects of it) obviously need improvement – what I have been able to offer here is only an experimental sketch. Further specification and elaboration of the mechanisms of movement are needed; the complexity involved in the successful operation of puppets and automata gives an idea of the complexity of the biomechanics, as Aristotle himself points out.²³ But I conclude that Aristotle, certainly no less than Lucretius, and no less even than contemporary scientists, conceived of mechanistic (biomechanical) explanations. There is nothing about his scientific method, including his teleology, that precludes him from offering mechanistic explanations – on the contrary, his scientific method is designed to include mechanics as a major part of the mixed mathematical and physical sciences. Indeed, although Aristotle has been cast as the arch-teleologist, and Aristotelianism as a philosophy brought down by the triumph of the “mechanistic worldview,” it is possible to view matters quite differently.

²³ *MA* 7, 701b2–17; *GA* 2.1, 734b9–15. See also the discussion of these passages in Berryman 2007: 361–362.

Aristotle or some other philosopher self-consciously following the methodology of *APo.* (and following it closer than Aristotle often seems to in other surviving scientific works) authored *Mech.*, the first systematic text in the science of mechanics. This work fills out a mechanical science that gives real depth to the biomechanical and mechanistic explanations referred to in Aristotle's *Physics* and his psychological, physiological, and biological works. It is a strange turn of events that the author of or inspiration for the first substantial work on mechanics, and a philosopher who in his own physical, biological, and psychological works called attention to mechanistic explanations, has so often been put down as a naïve teleologist. I conclude instead that he is the original and classical mechanistic philosopher.

TELEOLOGY IN THE ANCIENT WORLD

Philosophical and Medical Approaches

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