One of philosophical preoccupations of much recent work in the history of early-modern philosophy is the mechanical philosophy. According to the mechanical philosophy, everything in nature is to be explained in terms of the size, shape, and motion of the small parts that make up a sensible body. In essence, for the mechanical philosophy, the whole world can be treated as if it were a collection of machines. The mechanical philosophy is in explicit contrast with the Aristotelian philosophy of the schools. For an Aristotelian physicist, natural philosophy is ultimately grounded in the irreducible tendencies bodies have to behave one way or another, as embodied in their substantial forms. Some bodies naturally fall, and others naturally rise; some are naturally cold, and others are naturally hot; some are naturally dry, and others are naturally wet. Increasingly, historians of the period are grasping that one of the most important questions for the historian of seventeenth-century philosophy is that of understanding how the philosophical programs of the great philosophers of the period are connected with the mechanical philosophy. I completely agree with this trend: the mechanical philosophy was, in a sense, the motor that drove the transformation from Aristotelian scholastic philosophy and the obscurities of Renaissance thought to the figures who are generally acknowledged to be the first moderns, including, for example, Descartes, Hobbes, Spinoza, and Leibniz. I do not want to suggest, as some writers assume, that the mechanical philosophy was the only important alternative to Aristotelian natural philosophy in its day, and that anyone who was not an Aristotelian must have been a mechanist.¹

¹ When Descartes was writing, there were alchemists, Platonists, and Telesians who believed in hot and cold as basic principles, followers of Gilbert who saw magnetism as basic, and many others not so easily categorizable. For a survey of the scientific world as it was in the generation before Descartes came onto the scene, see chapter 5 of Brian P. Copenhaver and Charles B. Schmitt, Renaissance Philosophy (Oxford and New York: Oxford University Press, 1992).
But that understood, it certainly emerged in the course of the seventeenth century as one of the principal alternatives, if not the principal alternative to the dominant Aristotelianism.

But despite all of the recent attention to the mechanical philosophy, the mechanical philosophy itself is still relatively little understood. In particular, there has been very little study of the relation between the science of mechanics and the mechanical philosophy. That is the project in this essay. To focus the investigation, I intend to concentrate on one particular figure, René Descartes, one of the founders of the mechanical philosophy properly understood. I shall begin with an overview of mechanics as it was practiced in the years before Descartes came onto the scene. Then I shall turn to Descartes himself and examine the role that mechanics and machines play in his thought. I shall argue that in forging the mechanical philosophy, Descartes profoundly transformed not only natural philosophy but mechanics as well, and that the new mechanical philosophy represented a rupture not only with Aristotelian natural philosophy but, in a way, with the science of mechanics as well. At the same time, I shall argue, it was the connection between mechanics and the new mechanical philosophy that allowed Descartes’ new science to remain intelligible to the adherents of the Aristotelian tradition he rejected and intended to replace.

MECHANICS AND NATURAL PHILOSOPHY: THE SIXTEENTH-CENTURY TRADITION(S)

The science of mechanics thrived in sixteenth-century Italy. The major ancient traditions that fed into Renaissance and early modern mechanics were that of pseudo-Aristotle and that of Archimedes. Aristotle’s *Physica* was widely edited, commented on, and studied in the schools. But in addition to the *Physica*, there was another widely circulated Aristotelian text, one that dealt with mechanics, the *Mechanica* or *Mechanica Problemata*, attributed to Aristotle in the Renaissance, though now known to be a somewhat later text. In the corpus of Archimedes’ surviving works, one is particularly important for mechanics in the sixteenth and seventeenth centuries: *On the Equilibrium of Planes*. These two somewhat different traditions came together when both texts were rediscovered in the Renaissance. Figures such as Benedetti, Tartaglia, Guidobaldo del Monte, and even Galileo combined elements of these two traditions, along with some pieces of others and


some original speculations, to produce a genuine renaissance in the science of mechanics.5

What was it that united these texts and made them all instances of the same program? One simple answer is that mechanics is concerned with machines: as Guidobaldo put it in his influential Mechanicorum liber (1577), “mechanics can no longer be called mechanics when it is abstracted and separated from machines.”6

Aristotle and Archimedes offer somewhat different treatments of machines. Aristotelian mechanics is, in general, very, very concrete. The author of the Mechanica never lost sight of the physical embodiment of the machines and the effect that that has on our understanding of how they work: the science of mechanics treated in the Mechanica was a science of real material machines in a real material world, dealing with things made of real materials that have physical properties, things that bend, break, and wiggle. Archimedean mechanics, on the other hand, was much more abstract and mathematical. In On the Equilibrium of Planes, Archimedes begins with a number of theorems in what we would call statics, the science of bodies in equilibrium configurations. The problems were reduced to their geometrical bare bones and solved as such. The author of the Aristotelian Mechanica dealt with real machines made out of real materials. But the objects Archimedes considered were highly idealized. When talking about the balance, he assumed point weights and balance beams that are mathematical lines. Archimedes gives a theory of machines, perhaps, but the machines that interest him are not of this world.

Even though they differ in important respects, the Aristotelian and Archimedean traditions in mechanics both centered on machines, as did the later tradition to which they give rise. But what does it mean to be a machine? In the traditional accounts of mechanics, a machine was defined in terms of its utility, that is to say, in terms of human ends. It was a science of things useful to us. The Aristotelian author of the Mechanica wrote in the very opening of the treatise:

Nature often operates contrary to human interest; for she always follows the same course without deviation, whereas human interest is always changing. When, therefore, we have to do something contrary to nature, the difficulty of it causes us perplexity and art has to be called to our aid. The kind of art which helps us in such perplexities we call Mechanical Skill.7

This was the subject matter of mechanics for pseudo-Aristotle: the study of artificial things, things constructed to do particular tasks for us that nature herself, left

5. See Stillman Drake, and I. E. Drabkin, eds., Mechanics in Sixteenth-Century Italy (Madison: University of Wisconsin Press, 1969). This volume contains important selections from these authors in English translation, together with an introductory essay that remains an invaluable guide to the subject.

6. “Neque enim amplius mechanic, si à machinis abstrahatur, et seiungatur, mechanic potest appellari.” Guidobaldo del Monte, Mechanicorum liber (Pisa, 1587), praefatio (unpaginated), translated in Drake and Drabkin, Mechanics, p. 245.

unaided, does not do. The conception of mechanics that focuses on the artificial-ity and the utility of machines was also important in the sixteenth century. For example, Guidobaldo opens his *Mechanicon liber* with the following implicit definition of the domain of mechanics:

> For whatever helps manual workers, builders, carriers, farmers, sailors, and many others (in opposition to the laws of nature)—all this is the province of mechanics.  

Given human interests, it is not surprising that mechanics as practiced focused on the particular machines it did from early on. The lever, the balance, the inclined plane, and, later, when gunnery became important, the motion of projectiles: they are all tools that enable us to do various things that we want to have done.

Embedded in this conception of the domain of mechanics was a certain conception of the natural world, the distinction between the natural and the artificial, and a certain related conception of the relations between the science of physics (natural philosophy) and the science of mechanics. For sixteenth-century Italian mechanics, as for Aristotle and Archimedes, there was a real division between physics on the one hand, and mechanics on the other. In the terminology of the sixteenth and early seventeenth century, mechanics, together with astronomy, optics, and music, were “middle sciences” (*scientiae mediae*) or branches of “mixed mathematics” (*mathematica mixta*), branches of mathematics that used physical premises but were distinct from the physics from which they borrowed. Natural philosophy (physics) treats natural things as they are in themselves, inquiring into their essences and the true causes of natural (physical) phenomena. But things in nature do not always do what we want them to do. Mechanics, on the other hand, is the science of the artificial, natural things as they are configured into devices for our benefit. In this way, it is a supplement to physics proper: it treats at least certain kinds of things not treated in physics, in particular, artificial things, machines.

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8. “Quandoquidem quodcunque Fabris, Architectis, Baiulis, Agricolis, Nautis, et quâm plurimus aliis (repugnantibus naturae legibus) optulatur; id omne mechanicum est imperium.” Guidobaldo del Monte, *Mechanicon liber*, praeatio (unpaginated), translated in Drake and Drabkin, *Mechanics*, p. 241. The fact that machines are made for particular purposes is one of the features of machines that Dennis Des Chene emphasizes in chapter 4 of *Spirits and Clocks: Machine and Organism in Descartes* (Ithaca: Cornell University Press, 2000). Des Chene provides a very elegant discussion of the machine analogy in Descartes as it applies to humans and other living creatures. Though my own orientation in this essay is somewhat different from Des Chene’s, I have learned a great deal from his work.


And, similarly, physics contributes to mechanics. Machines are, of course, made up of natural materials (wood, metal, ropes, etc.), which have their own natural properties. Mechanics must make use of those properties in explaining the behavior of machines. So, for example, heaviness plays a major role in explaining the simple machines (lever, screw, balance, etc.), all of which use human or animal force to overcome the natural effects of heaviness, and shows the mechanic how to lift weights in different ways. Whether one considers them as Archimedean idealizations or as Aristotelian concreta, treatises on mechanics all assumed that that one was dealing with heavy bodies, bodies that tend to fall to the center of the earth. The question of the cause of heaviness and freefall lay outside of the domain of mechanics, and in the domain of physics. It was one of the premises that the mechanic could borrow from the distinct science of physics.11

Now, when you talked about physics in the sixteenth and early seventeenth century, it was very difficult to avoid Aristotle. Especially interesting in this connection is the variety of attitudes toward Aristotle’s physics among writers on mechanics in the period. Some practitioners accept Aristotle quite willingly, but others reject him quite completely. In this way, even though mechanics is connected with the science of physics, it is not necessarily connected with one physics or another. Specific approaches to projectile motion, Benedetti’s for example, do entail giving up elements of Aristotle’s physics of motion, to be sure. But it is fair to say that mechanics as practiced in these figures is often combined with a commitment to elements of an Aristotelian physics, as in the case of Guidobaldo.12

Though the mechanical philosophy will later set itself against Aristotelian natural philosophy, the science of mechanics, as practiced in sixteenth-century Italy, is not, in and of itself, anti-Aristotelian. It was by no means clear that doing mechanics entailed one particular natural philosophy over another; in particular, it did not entail being anti-Aristotelian.

DESCARTES AND THE MECHANICAL PHILOSOPHY

At the end of his *Principia*, Descartes told the reader, “I have described this earth and indeed the whole visible universe as if it were a machine: I have considered


only the various shapes and movements of its parts” (Pr IV, 188). Later in the *Principia*, he wrote:

I do not recognize any difference between artifacts and natural bodies except that the operations of artifacts are for the most part performed by mechanisms which are large enough to be easily perceivable by the senses—as indeed must be the case if they are to be capable of being manufactured by human beings. The effects produced in nature, by contrast, almost always depend on structures which are so minute that they completely elude our senses. (Pr IV, 203)

Similarly, Descartes suggested to an unknown correspondent in March 1642, seeking to clarify his position, that “all the causes of motion in material things are the same as in artificial machines” (AT V, 546). In his *Traité de l’homme* of 1633, Descartes even assimilated the human body to a machine. In the opening pages of that work, Descartes imagined God to have created a very peculiar machine: “I suppose the body to be nothing but a statue or machine made of earth, which God forms with the explicit intention of making it as much as possible like us” (AT XI, 99). There is no doubt that this machine was supposed to represent the way our bodies actually are, as his account in the later “Description of the Human Body” (1647/8) made explicit (AT XI, 226).

But what role did mechanics, the science of machines, play in Descartes’ thought? Here I find some confusion and at least two different strains in Descartes’ thought. In his celebrated “tree analogy” in the introduction to the French edition of the *Principia*, Descartes wrote:

The whole of philosophy is like a tree. The roots are metaphysics, the trunk is physics, and the branches emerging from the trunk are all the other sciences, which may be reduced to three principal ones, namely medicine, mechanics and morals. (AT IXB, 14)

Understood in this way, mechanics, the theory of machines, is one of the fruits of physics, a science based on physics that helps us to control nature. Consistent with this view, Descartes sometimes argued that mechanics is a proper part of physics. And, therefore, in the *Principia* he wrote that “mechanics is a division or special case of physics, and all the explanations belonging to the former also belong to the latter; so it is no less natural for a clock constructed with this or that set of wheels

13. References to Descartes’ writings will be given as much as possible in the text. The standard original-language edition of Descartes’ writings is René Descartes, *Oeuvres de Descartes*, ed. Charles Adam and Paul Tannery, new edition (11 vols.) (Paris: CNRS/Vrin, 1964–74). This will be abbreviated “AT,” followed by volume (in Roman) and page number (in Arabic). References to Descartes’ *Principia Philosophiae* (1644; Fr. trans. 1647) are given by “Pr,” followed by the part (in Roman) and the section number (in Arabic). The best current translation is René Descartes, *The Philosophical Writings of Descartes*, ed. and trans. John Cottingham, Robert Stoothoff, Dugald Murdoch, and (for vol. III) Anthony Kenny (3 vols.) (Cambridge: Cambridge University Press, 1984–91). Since the passages quoted can readily be found in that edition, I will not cite the translation separately.
to tell the time than it is for a tree which grew from this or that seed to produce
the appropriate fruit” (AT IV, 203). Elsewhere, in a letter from 1637 he noted
that “the mechanics now current is nothing but a part of the true physics which,
not being welcomed by supporters of the common sort of philosophy [i.e., Aris-
totelian philosophy], took refuge with the mathematicians.” Taken literally, this
suggests a view that goes beyond what earlier practitioners of mechanics held, but
not by much. Though he identified mechanics as a part of physics, and not as a dis-
tinct and subordinate discipline, there is nothing in these statements that implies
that in addition to mechanics, physics doesn’t contain something more. Calling
mechanics a part of physics in this sense would seem to be just a linguistic point,
an expansion of the notion of physics and little more.

But elsewhere Descartes treated mechanics in a very different way, as
being genuinely foundational. In a number of places, Descartes fully identified
the laws of nature with the laws of mechanics. In the Discourse, for example,
Descartes talked about the “laws [regles] of mechanics” as being identical to the
laws of nature. Similarly, in the French edition of the Principles, Descartes
wrote:

I considered in general all the clear and distinct notions which our
understanding can contain with regard to material things. And I found no
others except for the notions we have of shapes, sizes and motions, and the
rules in accordance with which these three things can be modified by each
other—rules which are the principles of geometry and mechanics. And I
judged as a result that all the knowledge which men have of the natural
world must necessarily be derived from these notions. (emphasis added; Pr
IV, 203)

And so, Descartes held, both artificial and natural things, both animate and inan-
imate things must be explained in the same way. Descartes, in fact, goes so far as
to say that “my entire physics is nothing but mechanics.” And so, to explain any-
ting in Descartes’ physics, we must do a kind of reverse engineering. Descartes
wrote, again in the Principia:

14. Cf. Regulae ad directionem ingenii, Rule VI, AT X, 379, where Descartes criticizes “those
who study mechanics apart from physics and, without any proper plan, construct new instruments
for producing motion.”
15. Descartes to Plempius for Fromondus, 3 Oct. 1637, AT I, 420–421. See also Descartes to
Huygens, March 1638, AT II, 50 and 662 (note the significant variation between the two versions
of this text).
16. This is the conception of mechanics that is most of concern to Alan Gabbey in his essay,
“Descartes’s Physics and Descartes’s Mechanics: Chicken and Egg?” in S. Voss, ed., Essays on the
Gabbey does not seem to recognize that there is a second sense of the notion of mechanics in
Descartes, which I will argue below.
17. AT VI, 54: “. . . les regles des Mechaniques, qui sont les mesmes que celles de la nature
. . .” Cf. also “. . . the laws of my mechanics, that is, of my physics” [“. . . Mechanicae meae, hoc est
Physicae, leges . . .”] [Descartes to Plempius, 15 Feb. 1638, AT I, 524].
18. Descartes to Debeaune? 30 April 1639, AT II, 542.
Men who are experienced in dealing with machinery can take a particular machine whose function they know and, by looking at some of its parts, easily form a conjecture about the design of the other parts, which they cannot see. In the same way I have attempted to consider the observable effects and parts of natural bodies and track down the imperceptible causes and particles which produce them. (Pr IV, 203)\textsuperscript{19}

This sense of mechanics seems rather different than the earlier sense that we examined. On that first sense, mechanics is a part of physics, and is one of the final fruits of philosophical (i.e., scientific) inquiry. Call that sense of the term “non-foundational mechanics.” Non-foundational mechanics stands in contrast to this second sense in which Descartes takes himself to be interested in mechanics, the sense in which mechanics is taken to be foundational for his physics. Call this second sense “foundational mechanics.”

On the mechanical philosophy,\textsuperscript{20} mechanics (or, at least, foundational mechanics) subsumes physics: everything in physics now receives a mechanical explanation, that is, everything is explained as if it were a machine. This would seem to be a classic instance of intertheoretic reduction, where one discipline becomes reduced to another, physics to mechanics in this case. But matters are rather more complicated than this would suggest. It is extremely curious that when we look at Descartes’ actual physics, in either Le monde or the Principia, we find nothing that looks even vaguely like a sixteenth-century mechanics text. Descartes begins his physics in chapters 6 and 7 of Le monde and in part II of the Principia (§§36ff) with an account of the laws of nature. This is followed by an account of how the different elements he recognizes, differentiated from one another by shape, size, and motion, all arise from an initial chaos, and how the shape, size, and motion of the different corpuscles that make up bodies explain their properties. The Principia ends with a real tour de force, first an explanation of magnetism in terms of the motion of corpuscles (Pr IV 145ff), and then a sketch of an explanation of the senses (Pr IV 189f), again in terms of the corpuscles and their motion.

\textsuperscript{19} This follows the Latin version. The French version makes much the same point, but using the example of a watch of unknown construction in place of the more general “machinery” Descartes alludes to in the Latin. Given the freedom allowed to seventeenth-century translators, it isn’t clear whether this is Descartes’ alteration or the translator’s. For a discussion of some of the epistemological implications of this view, see Larry Laudan, “The Clock Metaphor and Hypotheses: The Impact of Descartes on English Methodological Thought, 1650–1670,” in his Science and Hypothesis (Dordrecht: Reidel, 1981), pp. 27–58.

\textsuperscript{20} It should be noted in this connection that I am using the term mechanical philosophy somewhat anachronistically here. Descartes himself does not use this term. The term seems first to appear in the writings of Robert Boyle in the early 1660s, roughly ten years after Descartes’ death, where it designates a conception of natural philosophy that unites a number of views considered by their originators in competition with one another, particularly those of Descartes and Gassendi. I would further claim that it was Boyle who created the idea of the mechanical philosophy, as it was used later in the century, though I will not argue that here. While recognizing the dangers, I will continue to use the term in connection with Descartes. On the history of the term mechanical philosophy, see Sophie Roux, La philosophie mécanique (1630–1690), unpublished doctoral thesis, École des Hautes Études en Sciences Sociales, 1996, pp. 19–26.
But there are no levers, no balances, no pulleys, nothing that looks like the sort of machine that was at the center of the tradition in mechanics in the sixteenth century. In October 1637, at the request of Constantijn Huygens, Descartes did write a short treatise on mechanics understood in what has become the classic sense, a treatise on the simple machines (pulley, lever, etc.), with a few general remarks on the principles behind his accounts. Descartes clearly knew what mechanics is. But, at the same time, nothing of that mechanics seems to appear in his actual physics. What is going on? In what way did Descartes think of his physics as mechanics?

**CARTESIAN MECHANICS: A MECHANICS WITHOUT HEAVINESS**

The project is, then, to make sense of the foundational mechanics, to understand what Descartes meant by “mechanics” when he said that his whole physics is mechanics.

Mechanics was the science of machines, artificial devices that are built in order to do work for us. Now, in practice, the kind of work that interested writers on mechanics in the sixteenth and early seventeenth centuries involved either lifting heavy bodies or shooting heavy bodies out of guns. The studies of machines designed to produce those effects stood at the center of traditional mechanics. In this context, of course, one deals with bodies that are heavy and fall or tend to fall to the center of the earth; mechanics would borrow premises that involve heaviness and free fall from physics, a separate discipline.

But, of course, if Descartes intended to make mechanics foundational and explain all physical phenomena in mechanistic terms, then these machines cannot be as central as they are to the subject matter of the mechanics of his predecessors. If everything in nature is to be explained as if it produced effects like a machine, then gravitation cannot be assumed; gravitation itself must also be explained, and, within the mechanical philosophy, it must be explained mechanistically. Or, to put it in another way, when mechanics subsumes physics, we can no longer appeal outside of mechanics to some distinct science to supply necessary premises concerning heaviness: the premises necessary for doing the traditional mechanics of heavy bodies must come from within the mechanical philosophy itself.

Descartes seemed to be aware of this. In his correspondence, Descartes discussed on a number of occasions some problems from traditional mechanics. And when he did so, he also made assumptions about heaviness and free fall. But it...
must be said that he was not very happy about this. On one such occasion Descartes wrote:

We shall suppose that each particle of a given heavy body always has a given force or tendency to descend, whether it is far from the center of the earth or close to it, and no matter how it is situated. As I have already remarked, this assumption is perhaps not true; yet we ought to make it nevertheless, in order to facilitate the calculation. In a similar way astronomers assume that the average motions of the stars are regular [égaux], in order to make it easier to calculate the true motions, which are irregular. (AT II, 227)

Consider also Descartes’ discussion of Galileo’s famous account of projectile motion. Galileo analyzed projectile motion as a combination of what we now call inertial motion (horizontal) at a constant speed together with free fall (vertical), where the distance fallen is proportional to the square of the time. Putting these two together, Galileo concluded that the path of a projectile is parabolic. Descartes wrote:

If we assume this, then it is very easy to conclude that the motion of projectiles should follow a parabolic line; but these assumptions being false, his conclusion may also be quite far from the truth. (AT II, 387)

The answer you get, in the end, is only as good as the assumptions that you make in the beginning. Because Descartes didn’t think that the assumptions were very good, the final result wasn’t either. Descartes did not want to reject the mechanics of the Aristotelian and Archimedean tradition altogether. Once we have established the proper account of heaviness in our mechanist physics, for example, we can then use this (non-foundational) mechanics for helping us to shoot straight and to lift heavy loads.

It is no surprise then that Descartes’ mechanist physics didn’t look much like earlier treatises on mechanics. Because the assumption of heaviness can no longer be borrowed from physics, a different discipline, the entire body of ancient and sixteenth century mechanics as it was actually practiced becomes unusable in Descartes’ foundational enterprise. The theories of levers and pulleys, inclined planes, and projectile motion that formed the central topics in mechanics for Galileo and his predecessors are not what Descartes had in mind when he identified mechanics with physics and made mechanics the foundational science.

This gives us a piece of the answer to the question as to why Descartes’ mechanical philosophy looks so different from the traditional mechanics from which it seems to have arisen. But it isn’t the whole story. Though we know at least something of what Descartes’ mechanics wasn’t, we do not yet know what it was.

To raise the question in a very concrete way, let’s continue a bit further down the path that we have been taking, and consider further Descartes’ account of heaviness. Descartes’ mechanical philosophy, his mechanist physics must establish the true nature of heaviness before that notion can be used in the mechanics of
heavy bodies. How can this be done? Though the full account is rather complex, in outline, Descartes’ account is as follows. Gravity, the tendency to fall toward the center of the earth, for Descartes, is explained in terms of the interaction between a body and the vortex of subtle matter that turns around the earth, he argues. Strictly speaking, bodies are pushed toward the center of the earth by colliding with the particles of subtle matter in the vortex. Descartes summarized his account of heaviness as follows:

My idea of weight is as follows. All the subtle matter which is between here and the moon rotates rapidly around the earth, and pushes towards it all the bodies which cannot move so fast. It pushes them with greater force when they have not yet begun to fall than when they are already falling; for, after all, if they are falling as fast as it is moving, it will not push them at all, and if they are falling faster, it will actually resist them.22

Descartes’ bodies, extended and extended alone, have no natural tendencies to move in one way or another. In particular, Cartesian bodies do not, as such, tend to fall toward the center of the earth or toward anything else. The true physics must explain why bodies fall toward the earth, and not just assume this as a premise, the way in which it is generally assumed by mechanics. And the means Descartes gives himself for such an explanation is size, shape, and motion alone: it is in those terms that we must explain why heavy bodies fall toward the center of the earth. Hence the Cartesian account of gravity in terms of the collision between a so-called heavy body and the particles of the subtle matter.

This is supposed to be an example of Descartes’ own approach to physics, which he identified with mechanics. But in what sense is the explanation of gravity that Descartes offers here mechanistic? In what sense is he explaining gravitation as if it were an aspect of the behavior of a machine, as he claims his physics is supposed to do? More generally, if it is not traditional mechanics that Descartes has in mind here, what exactly is it?

**CARTESIAN MECHANICS: MECHANICS WITHOUT TELEOLOGY**

To approach an answer to this question, let us go back to some of my earlier comments about machines and the science of mechanics. The machine is an artifact, constructed to do some particular piece of work. Considered as an artifact, it has an end, of course; it is constructed by an agent and for some purpose of interest to that agent. This conception of the machine is reflected in the science of mechanics, which is the science of the artificial, the science whose object is the construction and explanation of artifacts built to do things we need to have done. In pre-Cartesian mechanics, the artificial is contrasted with the natural, and the science of mechanics is contrasted with the science of physics or natural philosophy.

22. Descartes to [Debeaune], 30 April 1639, AT II, 544. Descartes’ account of gravity is treated at greater length in *Le monde*, chapter 11, and in Pr IV 23f.
If machines are defined in terms of their purposes, and natural things are not normally thought of as having purposes, then how can we talk about natural bodies in terms of machines? One way is this. We can imagine natural things as if they were machines, by imagining them as if they were artifacts, things constructed for a purpose. To say that a natural object is like a machine is to say that we can consider it as, or as if it had been made by someone for a purpose, God, perhaps, and explain it as such. And so, for example, at the beginning of the *Traité de l’homme*, Descartes imagined God having created the man/machine that is the subject matter of the treatise:

I suppose the body to be nothing but a statue or machine made of earth, which God forms with the explicit intention of making it as much as possible like us. Thus God not only gives it externally the colors and shapes of all the parts of our bodies, but also places inside it all the parts required to make it walk, eat, breathe, and indeed to imitate all those of our functions which can be imagined to proceed from matter and to depend solely on the disposition of our organs. We see clocks, artificial fountains, mills, and other such machines which, although only man-made, have the power to move of their own accord in many different ways. But I am supposing this machine to be made by the hands of God, and so I think you may reasonably think it capable of a greater variety of movements than I could possibly imagine in it, and of exhibiting more artistry than I could possibly ascribe to it. (AT XI, 120)

In this situation the natural human body is set along side an artifactual human body, a machine/body that God, the artifex maximus, has made. This artifact, this machine has its own purpose: to look and behave as much like a real human body as possible. Since God is the artisan here, of course the resemblance is exact. What is Descartes’ point here in positing such a strange object? As Descartes put it in a number of places in the treatise, the machine God creates “represents” what happens in the body.23 That is, we can conjecture that in our natural bodies, the phenomena in question are produced in the same way in which they are in the body of the machine God built to imitate us.

Elsewhere, Descartes took a somewhat different approach. I return to a passage quoted earlier in the essay:

Men who are experienced in dealing with machinery can take a particular machine whose function [*usus*] they know and, by looking at some of its parts, easily form a conjecture about the design of the other parts, which they cannot see. In the same way I have attempted to consider the observable effects and parts of natural bodies and track down the imperceptible causes and particles which produce them. (Pr IV, 203)

The idea here seems to be that we can look at nature through the eyes of the mechanic or engineer, and ask how he would build a machine whose purpose it

23. E.g., AT XI, 173.
would be to mimic nature in just the way God’s man/machine mimics us. What is the point of this? The point, as I understand it, is to argue that the natural object could be identical to the mechanical substitute that we imagine is being made. For any given natural thing with its particular behaviors, we can substitute a man-made artifact whose purpose it is to mimic nature.

We can talk about natural things as machines by attributing purposes to them; we can imagine them to be machines made for the purpose of producing certain behavior or phenomena. But there is another strategy we can use: we can bracket, or even eliminate, the purposes from machines, and in that way assimilate them to natural objects. In a certain sense, Descartes insisted, the purpose of a machine is something extrinsic to that machine, something that is imposed on the machine by us. And, Descartes argued, this is true not only of things mechanics make, but also of the kind of natural machines treated in his biology. In an important passage in Meditation VI, Descartes wrote:

[A] clock constructed with wheels and weights observes all the laws of its nature just as closely when it is badly made and tells the wrong time as when it completely fulfils the wishes of the clockmaker. In the same way, I might consider the body of a man as a kind of machine equipped with and made up of bones, nerves, muscles, veins, blood and skin in such a way that, even if there were no mind in it, it would still perform all the same movements as it now does in those cases where movement is not under the control of the will or, consequently, of the mind. I can easily see that if such a body suffers from dropsy, for example, and is affected by the dryness of the throat which normally produces in the mind the sensation of thirst, the resulting condition of the nerves and other parts will dispose the body to take a drink, with the result that the disease will be aggravated. Yet this is just as natural as the body’s being stimulated by a similar dryness of the throat to take a drink when there is no such illness and the drink is beneficial. Admittedly, when I consider the purpose of the clock, I may say that it is departing from its nature when it does not tell the right time; and similarly when I consider the mechanism of the human body, I may think that, in relation to the movements which normally occur in it, it too is deviating from its nature if the throat is dry at a time when drinking is not beneficial to its continued health. . . . As I have just used it, ‘nature’ is simply a label which depends on my thought; it is quite extraneous to the things to which it is applied, and depends simply on my comparison between the idea of a sick man and a badly-made clock, and the idea of a healthy man and a well-made clock . . . (AT VII, 84–5)²⁴

The telos is something imposed from the outside, imposed by us, both in the case of the artificial machine and in the case of the natural object. In an important sense, it isn’t really there.

²⁴. Descartes goes on in this passage to say that considered as a mind/body unity, the human being does have a nature, and it does make sense to say that the person is departing from its nature when ill. However, the case for a body taken alone (or an animal body) is parallel to that of a clock.
When we bracket the purpose of a machine, or, as the Meditation VI passage suggests, eliminate it altogether, what is left to the machine is simply its construction: purpose aside, a machine is just the kind of thing that a mechanic can make with the tools at his disposal, that is, something that works by size, shape, and motion. For traditional mechanics, a machine is an artifact, something made for a particular purpose. For Descartes, I suggest, a machine has become simply a collection of parts whose states are determined by the size, shape, and motion of those parts, as well as by the collisions among them. The focus of a Cartesian mechanics, a Cartesian mechanical philosophy, is not on the things that we can do with machines and the purposes for which we might construct them, but on the means at our disposal for constructing them, on the different configurations of size, shape, and motion that produce those effects.

Machines are made with a purpose; natural things are not. But this particular difference between the machine and the natural body to which it corresponds is irrelevant to Descartes’ project: his point in establishing a correspondence between the artificial machine and the natural body was that we can now explain everything that happens in the natural body in exactly the same way in which we explain what happens in the artificial machine. That is, we explain things in the natural world as if they had been made by a mechanic who has only parts of different sizes, shapes, and motions to work with when producing his effects. To return to a passage that I cited earlier, Descartes wrote:

For I do not recognize any difference between artifacts and natural bodies except that the operations of artifacts are for the most part performed by mechanisms which are large enough to be easily perceivable by the senses—as indeed must be the case if they are to be capable of being manufactured by human beings. The effects produced in nature, by contrast, almost always depend on structures which are so minute that they completely elude our senses. (Pr IV, 203)

When we explain how the effect of the machine is accomplished, its purpose doesn’t enter in: we explain the behavior of the watch using the kinds of resources available to the watchmaker when he builds such a machine, the wheels and springs and other small parts that work in terms of size, shape, and motion. The purpose of a machine may determine what behavior it is that we are trying to produce, but it does not enter into the way in which the behavior itself is produced. It is in this sense that the theory of gravitation that we briefly discussed above is mechanical: Descartes explains the heaviness of bodies in the terms one uses in explaining the behavior of a machine. In this way the (spring-driven) clock or the planetary system or the magnet (as Descartes understands it) or the rainbow can all be regarded as machines: their behaviors can be explained by Descartes strictly in terms of the size, shape, and motion of their parts.

There is, I suggest, a new sense of what it is to be a machine in Descartes. But with this change, Descartes has changed the subject matter of mechanics. The mechanics practiced before Descartes was the science of the artificial, in contrast with the natural; its focus was on how to do the things we want to do with the
means that nature has put at our disposal. And just as the notion of a machine before Descartes was infused with teleology, so was the notion of a science of mechanics: what its objects had in common was a common purpose, doing things that we want to have done. In this sense, the domain of the science of mechanics is defined by us and our needs, not in terms of some natural category of things in nature. But in Descartes, mechanics becomes not the science of machines, artifacts made to help us do things we want done, but the science of things that operate through the physical configuration of their parts. A new sense of mechanics emerges, free of teleology: mechanics becomes the science of complex bodies whose states are determined by the size, shape, and motion of their parts. In 1577 Guidobaldo wrote that “mechanics can no longer be called mechanics when it is abstracted and separated from machines.”

In essence, this is just what Descartes has done, produced a mechanics without machines in the sense that Guidobaldo and his contemporaries would have understood the term. Mechanics has become in Descartes more like mechanics in the modern (i.e., eighteenth-century) sense, the study of bodies in motion. In 1670, John Wallis published a book entitled *Mechanica, sive de motu* (London, 1670). A hundred years earlier, this title would have been unintelligible; after Descartes it was taken for granted.

It is this conception of the science of mechanics that Descartes wants to identify with physics: the claim is that everything in the physical world can be explained using the means at the disposal of the mechanic: the size, shape, and motion of the parts of a body. Once we have established a mechanical philosophy, a mechanical physics, we are, of course, free to study those special machines of particular utility to us, just as we can give special attention to the human body, a body of special interest to us as human beings; hence the sciences of (non-foundational) mechanics and medicine, two of the three ultimate fruits of the tree of philosophy. There, once we reach the branches of our tree of philosophy, we can also talk about machines and human bodies in more traditional teleological ways, about what makes them healthy or functional, as opposed to ill or broken. But insofar as the mechanical philosophy, the mechanics transformed into philosophy, is a natural philosophy, its subject matter cannot be defined in the artificial, unnatural, and teleological way that mechanics is traditionally characterized in terms of human interests.

The question of intertheoretical reduction and unification is quite important to recent work in the philosophy of science. The way in which scientists and mathematicians forge links between different scientific disciplines and attempt to subsume one into another is one of the important engines for scientific change. Descartes is well known for his unification of algebra and geometry and for his...

reduction of biology to physics. But the mechanical philosophy was probably his most significant such move, expanding mechanics in such a way that it now embodies all physics. What is surprising, though, is that when physics and mechanics merged, the resulting scientific program retained little of either program that preceded it. It certainly did not look very much like the Aristotelian physics that it was intended to replace. And as I have argued, it didn’t look very much like the mechanics from which it supposedly had its inspiration. It remained, in a sense, the theory of machines, but machines understood in a way very different from the way in which machines were understood in the tradition of mechanics that preceded Descartes. In that way, the passage from mechanics to the mechanical philosophy was not a smooth transition, but a very surprising rupture. It is ironic, but in understanding the world in terms of machines, Descartes had to set aside the theory of machines as it was then understood.

CONTINUITIES

I have argued that Descartes’ mechanical philosophy represented a major shift in the conception of the notion of a machine and the science of mechanics. But even leaving this change aside, the shift from Aristotelian natural philosophy to the new mechanical philosophy in Descartes’ thought is generally considered to represent a major shift in the European intellectual tradition, the very paradigm of a Kuhnian paradigm shift, a chasm across which communication would seem to be difficult if not impossible. The further changes in the notion of the mechanical that Descartes’ philosophy introduced might be thought to make the situation worse still. But, interestingly enough, this isn’t the case. Descartes and his Aristotelian teachers and predecessors certainly disagreed on a great deal. But the idea of the machine and the science of mechanics provided a link between the two worlds.

Now, if we think of the mechanist revolution as the transition between Aristotelian natural philosophy taken narrowly and the mechanistic natural philosophy that Descartes introduced, then it does, indeed, look as if we may well be dealing with a gap across which communication would seem to be impossible. What can be more different than the Aristotelian world of souls and forms and innate tendencies, and the Cartesian world of tiny machines? But there is another way of looking at the transition. The Aristotelian world contained more than just natural philosophy taken narrowly: it contained mechanics as well, the science of the artificial that complemented natural philosophy taken narrowly. If we now think of the Aristotelian world as including both natural philosophy, strictly considered, and mechanics, the science of the artificial that complemented natural philosophy taken narrowly, then the transition from the Aristotelian to the mechanist world looks rather different.

27. Because of this, it is wrong to imagine that there was a radical contrast between mathematical views of the world and Aristotelian, and to see the Scientific Revolution of the seventeenth century as the replacement of the one by the other. For such a view, see, e.g., Alexandre Koyré’s classic Galileo Studies (Atlantic Highlands: Humanities Press, 1978). For the sixteenth-century savant, there was no tension between the two: Aristotelian natural philosophy could coexist alongside mechanics.
Earlier I emphasized the extent to which Descartes transformed the science of mechanics. But however different it may have been from earlier mechanics, I have no doubt that Descartes’ enterprise was fully intelligible to the practitioner of pre-Cartesian mechanics, just as pre-Cartesian mechanics was fully intelligible to Descartes. Though Descartes excised the teleology from machines and the science of mechanics, the conception that he replaced it with was not unfamiliar to the Aristotelian. Even if we give up the characterization of mechanics in terms of artificial machines and their purposes, the idea of things that operate through the size, shape, and motion of their parts is as intelligible to the Aristotelian as it is to the Cartesian. After all, the mechanic built machines that operate through wheels, gears, and pulleys long before Descartes elevated their trade to the level of a natural philosophy. Though he focused on a different aspect of the machine than his predecessors did, the toolbox he had in mind in this connection would have been familiar to any working mechanic, even if Descartes saw more things as machines, oysters and magnets, for example, than did his Aristotelian counterpart.28

Descartes, in fact, depended on the fact that his enterprise was intelligible to his Aristotelian reader. In a famous passage in the *Meteors*, for example, he wrote the following:

\[\ldots\text{to avoid a breach with the philosophers, I have no wish to deny any further items which they may imagine in bodies over and above what I have described [i.e. small corpuscles of different sizes, shapes, and motions], such as \textquote{substantial forms}, their \textquote{real qualities}, and so on. It simply seems to me that my arguments must be all the more acceptable in so far as I can make them depend on fewer things. (AT VI, 239)}\r

There is, of course, something disingenuous in this passage: Descartes was, indeed, trying to put something past the Aristotelians, as he frankly told his then-disciple, Henricus Regius.29 Not for a minute did Descartes think that we need to posit forms and qualities. But at the same time the efficacy of the ruse depends on the fact that his mechanical philosophy shares a domain of intelligibility with the science of mechanics as understood by the Aristotelian: it depends on the fact that even the Aristotelian recognizes a domain in which it is possible and, indeed, proper to explain phenomena as the mechanic does, in terms of the size, shape, and motion of the parts of a body, and that that is not at all inconsistent with there

28. Treating living things as machines was not altogether foreign to the Aristotelian tradition in mechanics. In the *Mechanica*, for example, the author uses the tools of mechanics to explain a variety of natural phenomena, such as why pebbles on beaches are rounded (§ 15), or why when people stand from a sitting position they make an acute angle between the thigh and the lower leg (§ 30). Even from the point of view of the Aristotelian, there were some natural phenomena that are to be explained not in terms of forms, qualities, and prime matter, but in terms of the size, shape, and motion of its parts, as if they were machines. Descartes can be seen as just taking this a step (or many steps) further.

29. Descartes to Regius, January 1642, AT III, 492. Descartes also refers to this passage in the *Fourth Replies*, AT VII, 248–249; he seems to have been very proud of it.
being another domain in which explanation in terms of form and matter is appropriate. Descartes’ strategy was to argue that phenomena of dioptrics and meteors fall within the domain of the mechanical; he just neglected to say that for him, *everything* falls within this domain. Descartes made a similar observation in his *Principia Philosophiae*:

*I have used no principles in this treatise which are not accepted by everyone; this philosophy is nothing new but is extremely old and very common.*

I should also like it to be noted that in attempting to explain the general nature of material things I have not employed any principle which was not accepted by Aristotle and all other philosophers of every age. So this philosophy is not new, but the oldest and most common of all. I have considered the shapes, motions, and sizes of bodies and examined the necessary results of their mutual interaction in accordance with the laws of mechanics, which are confirmed by reliable everyday experience. And who has ever doubted that bodies move and have various sizes and shapes, and that their various different motions correspond to these differences in size and shape; or who doubts that when bodies collide bigger bodies are divided into many smaller ones and change their shapes? (Pr IV, 200)

Again, there is something a bit disingenuous here. Though the general mode of explanation in terms of size, shape, and motion was certainly accepted by the followers of Aristotelian mechanics in its appropriate domain, they would certainly deny that *all* natural phenomena can be so explained, just as Descartes would deny that some natural phenomena must be explained in terms of substantial form and prime matter. But again, Descartes was appealing to a common area of intelligibility in order to make his program acceptable to the Aristotelian. Even if the Aristotelian would balk at the claim that *everything* is explicable mechanically, he cannot claim not to understand it. Descartes was certainly right to assume that his Aristotelian reader could understand what he was up to. Consider, for example, the case of Libertus Fromondus, a professor of theology at the University of Louvain, a defender of the Aristotelian philosophy and a harsh critic of the Epicurean atomism then becoming particularly fashionable. Unsurprisingly, Fromondus was not at all sympathetic to Descartes’ project. In a letter from Fromondus to Plempius, 13 September 1637, he made the following remark about Descartes’ account of body in the *Meteors*:

That composition of bodies made up of parts of different shapes . . . by which they reciprocally cohere as by little hooks, seems excessively crass and mechanical. (AT I, 406)

30. Fromondus here was complaining specifically about the account of the composition of water, earth, ice, etc. from smaller parts in order to explain their general properties in the *Meteors*, AT VI, 233–234, 237–238.
Descartes immediately took offense at this, and saw it as a general challenge to his mechanical philosophy. In his reply (Descartes to Plempius for Fromondus, 3 Oct. 1637), he wrote:

If my philosophy seems too “crass” for him, because, like mechanics, it considers shapes and sizes and motions, he is condemning what seems to me its most praiseworthy feature, of which I am particularly proud. I mean that in my kind of philosophy I use no reasoning which is not mathematical and evident, and all my conclusions are confirmed by true observational data . . . So if he despises my style of philosophy because it is like mechanics, it is the same to me as if he despised it for being true. (AT I, 420–1)

Fromondus certainly did not approve of what Descartes was proposing, but there is no question but that he understood exactly what Descartes was up to.

In this way, machines and the science of mechanics, common both to Aristotelian thinkers and Cartesian, provided a clear pivot point between the two worlds, a point of common conception that enabled the two to remain intelligible to one another even as they were arguing for radically different ways of understanding the world.31

There is a tendency in the literature to think of the rise of the mechanical philosophy as if it were a relatively simple matter, as if the mechanical philosophy rose full blown and fully formed from the head of Zeus sometime in the early 1600s and quickly marched to victory over its outmoded and degenerate Aristotelian opponents. Things weren’t that simple. Aristotelian natural philosophy was to maintain its vigor (and its dominance in many circles) for some years to come. Furthermore, Descartes’ mechanical philosophy was only one strand among many in the anti-Aristotelian camp in the period; many of that period who we now tend to group with Descartes among the mechanists, such as Galileo, Gassendi, Mersenne, and Hobbes, saw one another as competitors first, and allies against Aristotelianism only second. (We must remember here that not everyone who opposed Aristotle in the early seventeenth century was anywhere near the scientific sensibility of those whom we group among the mechanists.) It will be some years, perhaps not until the 1660s, before we can talk with confidence about the

31. In this respect the domain of mechanics and the machinist’s workroom functioned as a kind of “trading zone” between the Aristotelian and the Cartesian mechanist, to use Peter Galison’s extremely fruitful anthropological analogy. See Peter Galison, Image and Logic: A Material Culture of Microphysics (Chicago: University of Chicago Press, 1997), chapter 9. Galison writes: “Two groups can agree on rules of exchange even if they ascribe utterly different significance to the objects being exchanged; they may even disagree on the meaning of the exchange process itself. Nevertheless, the trading partners can hammer out a local coordination despite vast global differences . . . [I]n focusing on local coordination, rather than global meaning, one can understand the way engineers, experimenters, and theorists interact” (pp. 783–784). To this one can add Aristotelians and Cartesians. I thank Roger Ariew for pointing out the obvious connection between my concerns in this section and Galison’s ideas.
mechanical philosophy, as opposed to a somewhat rag-tag collection of anti-Aristotelian programs that share some features but differ in other important respects. In this essay I have tried to document some aspects of how a mechanical philosophy arose in the case of Descartes, the way in which Descartes transformed the notion of mechanics when he placed it at the center of his own natural philosophy and the way in which machines and mechanics continued to connect Descartes’ thought to the intellectual landscape of his predecessors. But this is only part of a larger story.

32. See the remarks above in note 20.

33. This essay started life as two distinct and somewhat contradictory projects, one about the radical distinction between Descartes’ program and sixteenth-century mechanics, and the other about the continuity between Descartes and earlier thought, before I realized that the two stories are really complementary. They come together here for the first time. Earlier versions of this material were delivered at Virginia Tech, the University of Wyoming, the University of California, Berkeley, the Centre Alexandre Koyré (Paris), the Keeling Colloquium at University College London (where my presentation received a very useful commentary from Tom Sorrel), Syracuse University, Princeton University, the University of Virginia, and the Eastern Division APA (the memorial session for Margaret Wilson). It also served as the material for some of my seminars at the NEH Summer Seminar I co-directed with Roger Ariew in summer 2000. I would like to thank audiences at all of those presentations for their help, but especially Roger Ariew, my best critic.