OTHER VOLUMES IN THIS SERIES OF CAMBRIDGE COMPANIONS:

AQUINAS *Edited by* NORMAN KRETZMANN *and* ELEONORE STUMP
ARISTOTLE *Edited by* JONATHAN BARNES
FOUCAULT *Edited by* GARY GUTTING
FREUD *Edited by* JEROME NEU
HEGEL *Edited by* FREDERICK BEISER
HEIDEGGER *Edited by* CHARLES GUIGNON
HOBBES *Edited by* TOM SORRELL
HUME *Edited by* DAVID FATE NORTON
HUSSERL *Edited by* BARRY SMITH *and* DAVID WOODRUFF SMITH
KANT *Edited by* PAUL GUYER
LEIBNIZ *Edited by* NICHOLAS JOLLEY
LOCKE *Edited by* VERE CHAPPELL
MARX *Edited by* TERRELL CARVER
MILL *Edited by* JOHN SKORUPSKI
NIETZSCHE *Edited by* BERND MAGNUS
PLATO *Edited by* RICHARD KRAUT
SARTRE *Edited by* CHRISTINA HOWELLS
SPINOZA *Edited by* DON GARRETT

The Cambridge Companion to DESCARTES

Edited by John Cottingham

CAMBRIDGE UNIVERSITY PRESS

DANIEL GARBER

10 Descartes' physics

Physics and its foundations were central to Descartes' thought. Although today he is probably best known for his metaphysics of mind and body, or for his epistemological program, in the seventeenth century Descartes was at very least equally well known for his mechanistic physics and the mechanist world of geometrical bodies in motion which he played a large role in making acceptable to his contemporaries. In this essay I shall outline Descartes' mechanical philosophy in its historical context. After some brief remarks on the immediate background to Descartes' program for physics, and a brief outline of the historical development of his physics, we shall discuss the foundations of Descartes' physics, including his concepts of body and motion and his views on the laws of motion.

1. BACKGROUND

Before we can appreciate the details of Descartes' physics, we must appreciate something of the historical context in which it emerged and grew.

Most important to the background was, of course, the Aristotelian natural philosophy that had dominated medieval thought.[1] Aristotelian natural philosophy had come under significant attack in what came to be known as the Renaissance.[2] But it is important to realize that well into the seventeenth century, throughout Descartes' life, the Aristotelian natural philosophy was very much alive, and relatively well; it was what Descartes himself studied at La Flèche, and what was still studied there (and in most other schools in Europe and Britain) in 1650 when Descartes met his death in Sweden.[3]

The Aristotelian natural philosophy was a matter of enormous

complexity. But briefly, what concerned Descartes most directly in his own physics is the doctrine of substantial forms.[4] For the schoolmen, bodies were made up of prime matter and substantial form. Matter is what every body shares, while form is what differentiates bodies from one another. And so, it is form that explains why stones fall, and fire rises, why horses neigh and humans reason. There are, of course, numerous different ways of understanding what these forms were to the schoolmen.[5] Descartes was fond of thinking of them as little minds attached to bodies, causing the behavior characteristic of different sorts of substances. In the *Sixth Replies*, for example, he has the following remarks to make about the scholastic conception of heaviness which he was taught in his youth:

> But what makes it especially clear that my idea of gravity was taken largely from the idea I had of the mind is the fact that I thought that gravity carried bodies towards the centre of the earth as if it had some knowledge [*cognitio*] of the centre within itself. For this surely could not happen without knowledge, and there can be no knowledge except in a mind.
>
> (AT VII 442: CSM II 298)[6]

This natural philosophy will be one of Descartes' most important targets in his own writings on natural philosophy.

Descartes was by no means alone in opposing the philosophy of the schools. As I noted earlier, there had been numerous attacks on the Aristotelian natural philosophy by the time Descartes learned his physics at school, various varieties of Platonism, Hermeticism, the Chemical Philosophy of Paracelsus, among other movements.[7] But most important to understanding Descartes was the revival of ancient atomism. In opposition to the Aristotelian view of the world, the ancient atomists, Democritus, Epicurus, Lucretius, attempted to explain the characteristic behavior of bodies, not in terms of substantial forms, but in terms of the size, shape, and motion of the smaller bodies, atoms, that make up the grosser bodies of everyday experience, atoms which were taken to move in empty space, a void. Atomistic thought was widely discussed in the sixteenth century, and by the early seventeenth century it had a number of visible adherents, including Nicholas Hill, Sebastian Basso, Francis Bacon, and Galileo Galilei.[8] When all was said and done, Descartes' physics wound up retaining a number of crucial features of the physics he was taught in

school, and differing from the world of the atomists; most notably, Descartes rejected the indivisible atoms and empty spaces that characterize atomistic physics. But Descartes' rejection of the forms and matter of the schools, and his adoption of the mechanist program for explaining everything in the physical world in terms of size, shape, and motion of the corpuscles that make up bodies, is hardly conceivable without the influence of atomist thought.

2. THE DEVELOPMENT OF DESCARTES' SYSTEM

Descartes attended the Jesuit college of La Flèche, where he received a full course in Aristotelian natural philosophy.[9] In addition to Aristotle, taught at La Flèche from a humanist perspective, Descartes received an education in mathematics quite unusual for the Aristotelian tradition.[10] But Descartes' career as a natural philosopher, properly speaking, begins with his meeting with Isaac Beeckman in November of 1618 in the town of Breda. Descartes, then twenty-two years old and out of school for only two years, had been leading the life of a soldier, apparently intending to be come a military engineer. Beeckman, eight years the young Descartes' senior, was a devoted scientific and mathematical amateur, and had been for some years; his journals, rediscovered only in this century, show an interest in a wide variety of scientific and mathematical subjects. The journals also give the record of the conversations between the two young men. It is clear from those records that Descartes was very much drawn into the new mechanistic and mathematical physics that Beeckman was enthusiastically (if unsystematically) developing. Beeckman set problems and questions for his younger colleague, and in his journal are the records of Descartes' struggles over a wide variety of questions in harmony and accoustics, physics, and mathematics, all approached in a decidedly non-Aristotelian way, attempting to apply mathematics to problems in natural philosophy.[11] There is little in these early writings that suggests Descartes' own later physics in any real detail, to be sure; indeed, there is every reason to belived that the young Mr. du Peron, as Descartes styled himself at that time, subscribed to the doctrines of atoms and the void that Beeckman held and he, Descartes, was later to reject.[12] But though the actual contact lasted only a few months (Beeckman left Breda on 2 January 1619), the effects were profound. As he wrote to Beeckman

on 23 April 1619, a few months after parting: "You are truly the only one who roused my inactivity, who recalled from my memory knowledge that had almost slipped away, and who led my mind, wandering away from serious undertakings, back to something better" (AT X 162–3: CSMK 4).

The decade or so that followed the meeting with Beeckman was very productive for Descartes. There is every evidence that it was then that he worked out his celebrated method, his geometry, and important parts of his theory of light, in particular, his law of refraction.[13] From discussions in the *Rules for the Direction of the Mind*, there is also reason to believe that he was also concerned with other problems, like that of the nature of magnetism.[14] Furthermore, in the *Rules* there are also evidences of his interest in the foundations of the mechanical philosophy that now characterized his thought. In particular, in his doctrine of simple natures, he seems to have presented the seeds of an argument that everything in the physical world is explicable in terms of size, shape, and motion. In the later sections of the *Rules* we also have a strong suggestion of the doctrine of the identification of body and extension that characterizes his mature thought.[15]

But the mature natural philosophy only begins to emerge in the late 1620s, after Descartes sets aside the composition of the *Rules*, and turns to the construction of his full system of knowledge. Important here is, of course, the now lost metaphysics of the winter of 1629–30, which, for Descartes, was clearly connected with the foundations of his science.[16] But at the same time that he was worrying about the soul and God, he was also working on the sciences themselves. Letters from 1629 and 1930 show that he was working on the theory of motion, space, and body, on optics and light, on the mechanist explanation of the physical properties of bodies, on the explanation of the particular atmospheric and clestial phenomena, and anatomy.[17] This work culminated in 1633 with the completion of *The World*. *The World*, as it comes down to us, is composed of two principal parts, the *Treatise on Light*, and the *Treatise on Man*. The *Treatise on Light* deals with physics proper. After a few introductory chapters, Descartes envisions God creating a world of purely extended bodies in the "imaginary spaces" of the schoolmen. He then derives the laws those bodies would have to obey in motion, and argues that set in motion and left to themselves, they would form

the cosmos as we know it, innumerable stars around which travel planets, and shows how features of our world like gravity and heaviness would emerge in that context. In this way he explains many features of our physical world without appeal to the substantial forms of the schoolmen. The *Treatise on Man*, on the other hand, deals with human biology. Imagining God to have made from this extended stuff a machine that resembles our bodies, Descartes shows how much explained by the schoolmen in terms of souls can be explained in terms of size, shape, and motion alone.

This sketch of a mechanical world was not to be published in Descartes' lifetime, though. When Descartes found out that Galileo had been condemned in Rome in 1633, he withdrew his *World* from publication, and, indeed, vowed not to publish his views at all.[18] However, his vow was short-lived. Though *The World* never did appear in Descartes' lifetime, by September or October of 1634, Descartes was at work on a new project, and by March 1636, a new work was finished.[19] The work in question was a collection of three scientific treatises in French, the *Geometry*, the *Optics*, and the *Meteorology*, gathered together and published in June of 1637 with an introduction, the *Discourse on the Method*. Much of the work that appears in these writings dates from much earlier. But what is distinctive about this work is the way in which it is presented. A central feature of the *Discourse* and *Essays* is the lack of the full framework of physics and metaphysics that, Descartes admitted, lay under the samples of work that he presented. The full system was sketched out, to be sure. In Part IV of the *Discourse* Descartes presented an outline of his metaphysics, and in Part V a sketch of the physics of *The World*. But, as Descartes explained in Part VI of the *Discourse*, the actual scientific treatises that follow give just the results of his investigations; the material in the *Optics* and *Meteorology* is presented hypothetically, using plausible but undefended assumptions and models, not because Descartes thought that this was the best way to present a body of material, but because in this way he could present his results without revealing the details of his physics that he knew would raise controversy.[20] The *Essays* contained much of interest, including the laws of refraction, a discussion of vision, and Descartes' important analysis of the rainbow. But conspicuously missing was any discussion of Copernicanism, or any account of Descartes' doctrine of body as essentially extended.

The reception given to the *Discourse* and *Essays* must have been sufficiently encouraging, for by the late 1630s, Descartes decided to embark on a proper publication of his system, set out in proper order, beginning with the metaphysics and the foundations of his physics. First to be completed was the *Meditations*, finished in the spring of 1640, and published in August of 1641. Although the *Meditations* are mainly concerned with metaphysical issues, they do contain elements of the foundations of Descartes' physics, including the existence of God (essential for grounding the laws of motion, as we shall see), and the existence and nature of body. In January 1641, on the eve of the publication of the *Meditations*, Descartes confided to Mersenne:

> I may tell you, between ourselves, that these six *Meditations* contain all the foundations of my physics. But please do not tell people, for that might make it harder for supporters of Aristotle to approve them. I hope that readers will gradually get used to my principles, and recognize their truth, before they notice that they destroy the principles of Aristotle.
>
> (AT III 297–8: CSMK 173)

But more directly important for the dissemination of Descartes' views on the natural world is the publication of the *Principles of Philosophy*.

Descartes began to contemplate the publication of his complete physics as early as the autumn of 1640, while the *Meditations* were circulating and he was awaiting the objections that he intended to publish together with his answers. Originally Descartes had planned to publish a textbook of his philosophy in Latin, unlike *The World* and the *Discourse*, together with an annotated version of the *Summa* of Eustachius a Sancto Paulo, a textbook widely used in the schools. In this way, Descartes thought, he could demonstrate the weakness of the standard Aristotelian physics, and the superiority of his own mechanical philosophy.[21] This plan was soon set aside in favor of a direct exposition of his own views.[22] The first parts of the incomplete work went to the printer in February 1643, and appeared in July of 1644.[23] The work proved popular enough to issue in a French version in 1647. Though Descartes himself did not do the translation, many of the significant changes between the Latin and French editions suggest that he took a real interest in the preparation of the new edition.

Descartes represents the project to his friend Constantijn Huygens as if the *Principles* were merely a translation of *The World*. Refering to some disputes he was involved with at the University of Utrecht, Descartes writes: "Perhaps these scholastic wars will result in my *World* being brought into the world. It would be out already, I think, were it not that I want to teach it to speak Latin first. I shall call it the *Summa Philosophiae* to make it more welcome to the scholastics" (AT III 523: CSMK 209–10). But the *Principles* is much more than a translation of *The World*. Leaving aside the numerous places in which Descartes has significantly revised and clarified his views, the structure is altogether different. Unlike *The World*, the *Principles* begins with an account of Descartes' first philosophy, his metaphysics. Parts II–IV correspond more closely to the contents of *The World*. Part II deals with the notions of body, motion, and the laws of motion, corresponding roughly to the rather informal exposition of chapters 6 and 7 in *The World*. Parts III and IV correspond roughly to chapters 8–15 in *The World*. As in the earlier work, Descartes presents and defends a vortex theory of planetary motion, a view that is unmistakably Copernican, despite attempts to argue that on his view, the Earth is more truly at rest than it is in other theories. But in the *Principles*, light lacks the central organizing role that it has in *The World*, and the *Principles* contains discussions of a number of topics, including magnetism, for example, that do not appear at all in *The World*. Clearly the *Principles* is something other than *The World* with a classical education.

With the *Principles* we have what can be considered a canonical presentation of Descartes' views in physics. While the earlier works present important insights, as do discussions of various issues in Descartes' correspondence, the *Principles* will be our main text in unraveling the complexities of Descartes' physical world.

3. BODY AND EXTENSION

Descartes' natural philosophy begins with his conception of body. For Descartes, of course, extension is the essence of body or corporeal substance. Or, to use the technical terminology that Descartes adopted in the *Principles*, extension is the principal attribute of corporeal substance. For Descartes, as for many others, we know substances not directly but only through their accidents, properties,

qualities, etc. But among these, one is special, Descartes holds. And so, in the *Principles* Descartes writes: "And indeed a substance can be known from any of its attributes. But yet there is one special property of any substance, which constitutes its nature and essence, and to which all others are referred" (*Principles* Part I, art. 53). This special property is extension in body, and thought in mind. All other notions "are referred" to this special property insofar as it is through the notion of extension that we understand size, shape, motion, etc., and it is through the notion of thought that we understand the particular thoughts we have, Descartes claims.[24] The notion of extension is so closely bound to the notion of corporeal substance that, for Descartes, we cannot comprehend the notion of this substance apart from its principal attribute. Descartes writes in the *Principles*:

> When [others] distinguish substance from extension or quantity, they either understand nothing by the name 'substance,' or they have only a confused idea of an incorporeal substance, which they falsely attribute to corporeal substance, and leave for extension [which, however, they call an accident] the true idea of a corporeal substance. And so they plainly express in words something other than what they understand in their minds.
>
> (*Principles* Part II, art. 9)[25]

Elsewhere Descartes suggests that there is only a conceptual distinction or "distinction of reason" (*distinctio rationalis*) between corporeal substance and its principal attribute.[26] In addition to the principal attribute of body, extension, which is inseparable from body, Descartes recognizes what he calls modes, particular sizes, shapes, and motions that individual bodies can have. Although not essential to body, the modes Descartes attributes to bodies must be understood *through* extension; they are *ways* of being extended for Descartes.[27] In this way insofar as they are not modes of extension, colors and tastes, heat or cold are not really in bodies but in the mind that perceives them.

It is important to recognize that while Descartes holds that the essence of body is extension, he does not understand the notion of an essence in precisely the way his scholastic contemporaries did. Put briefly, basic to scholastic metaphysics is the distinction between a substance and its accidents.[28] Now, certain of those accidents are especially important, those that constitute the essence or nature of that substance. A human being, for example, is essentially a rational

being and an animal; take either of those away from a substance, and it is no longer human. But nonessential accidents bear a completely different relation to the substance; they may be lost without changing the nature of the substance. Now, some of those accidents are the sorts of things that can only be found in human beings. Risibility and the actual act of laughing were thought to be possible only for something that has reason.[29] But many other accidents (color, size, etc.) bear no such relation to the essence; while such accidents must be understood as being in *some* substance or other, they are not necessarily connected to the essence of the human being. In this sense the Aristotelian framework allows for there to be accidents which are, as it were, tacked onto substances which are otherwise conceived of as complete. This is quite foreign to Descartes' way of thinking. For him *all* of the accidents in a corporeal substance must be understood through its essence, extension; there is nothing in body that is not comprehended through the essential property of extension. In this way Cartesian bodies are just the objects of geometry made real, purely geometrical objects that exist outside of the minds that conceive them.

Though there is every reason to believe that Descartes held the conception of body as extension from the late 1620s on, he offers little in the way of serious argument for the claim before 1640 or so.[30] But the question is taken up in depth in the writings that follow, mainly the *Meditations* (along with the *Objections and Replies*) and the *Principles of Philosophy*. Basic to the argument is the celebrated proof Descartes offers for the existence of the external world. While there are some significant differences between the versions that Descartes gives in different places, all of the versions of the argument turn on the fact that we are entitled to believe that our sensory ideas of bodies derive from bodies themselves. In the version Descartes offers in the *Meditations*, this claim is grounded in the fact that we have a great inclination to believe this, and the nondeceiving God has given us no means to correct that great inclination;[31] in the version in the *Principles* it is grounded in the fact that "we seem to ourselves clearly to see that its idea comes from things placed outside of us" (*Principles* Part II, art. 1). But, Descartes claims, the body whose existence this proves is not the body of everyday experience; when we examine our idea of body, we find that the idea we have of it is the idea of a geometrical object, and it is

this Cartesian body whose existence the argument proves. Thus Descartes concludes the version of the argument in the Sixth Meditation as follows:

> It follows that corporeal things exist. They may not all exist in a way that exactly corresponds with my sensory grasp of them, for in many cases the grasp of the senses is very obscure and confused; but indeed, everything we clearly and distinctly understand is in them, that is, everything, generally speaking, which is included in the object of pure mathemathics.
>
> (AT VII 80; CSM II 55)

In this way the argument for the existence of the external world serves not only to restore the world lost to the skeptical arguments of the First Meditation; but also to replace the sensual world of colors, tastes, and sounds with the spare geometrical world of Cartesian physics.

But, of course, this just pushes the investigation one step back; for this argument plainly depends on the view that our idea of body is as Descartes says it is, the idea of something that has geometrical properties and geometrical properties alone. To establish this conclusion, Descartes seems to appeal to at least three separate arguments, what might be called the argument from elimination, the argument from objective reality, and the complete concept argument.

While it is suggested in the wax example in the *Meditations*,[32] the argument from elimination appears most explicitly in the *Principles*. In *Principles* Part II, art. 4, Descartes claims to show "that the nature of matter, or of body regarded in general does not consist in the fact that it is a thing that is hard or heavy or colored or affected with any other mode of sense, but only in the fact that it is a thing extended in length, breadth, and depth." The argument proceeds by considering the case of hardness (*duities*). Descartes argues that even if we imagined bodies to recede from us when we try to touch them, so that "we never sensed hardness," things "would not on account of that lose the nature of body." He concludes: "By the same argument it can be shown that weight and color and all of the other qualities of that sort that we sense in a material body can be taken away from it, leaving it intact. From this it follows that its nature depends on one of those qualities" (*Principles* Part II, art. 4, Latin version).[33] The argument seems to be that extension must be the essence of body because all other accidents can be eliminated with-

out thereby eliminating body, and so, without extension, there can be no body.

But, interesting as this argument is, it doesn't seem to do the job. Descartes needs to establish that our idea of body is the idea of a thing whose only genuine properties are geometrical, a thing that *excludes* all other properties. But what the strategy in this argument establishes is that our idea of body is the idea of a thing at least *some* of whose properties must be geometrical. From the fact that we can conceive of a body without hardness, or color, or warmth, it does not follow that *no* body is really hard, or colored or warm, any more than it follows from the fact that we can conceive of a nonspherical body that no body is really spherical. At best the argument from elimination establishes that the essence of body is extension in the weaker Aristotelian sense, and not in the stronger Cartesian sense.

What I have called the argument from objective reality is suggested most clearly in the Fifth Meditation, whose title promises an investigation of "the essence of material things. . . ." When we examine our idea of body, Descartes claims, we find that what is distinct in our ideas of body is "the quantity that philosophers commonly call continuous, or the extension of its quantity, or, better, the extension of the thing quantized, extension in length, breadth, and depth . . ." (AT VII 63: CSM II 44). His reasoning seems to be something like this. What strikes Descartes as extremely significant about the geometrical features of our ideas of body is that we can perform proofs about those features, and demonstrate geometrical facts that we did not know before, and that we seem not to have put into the ideas ourselves. But, Descartes notes, "it is obvious that whatever is true is something, and I have already amply demonstrated that everything of which I am clearly aware is true" (AT VII 65: CSM II 45). Descartes seems to assume that whatever is true must be true of *something*, and so he concludes these geometrical features we find in our ideas of body must, in some sense, exist. At this stage in the argument we cannot, of course, conclude that they exist outside the mind. And so, Descartes concludes, they exist as objects normally exist in the mind, as objects of ideas, as objective realities. And so, Descartes takes himself to have established, our ideas of bodies really have the geometrical properties we are inclined to attribute to them.

But what does this argument really show? It certainly can be seen

to establish that our idea of body is the idea of something that has geometrical properties. But Descartes wants to establish a stronger claim, that bodies not only *have* geometrical properties, but that they have geometrical properties *alone*, that is, that they *lack* all other properties. So far as I can see, the argument suggested in the Fifth Meditation falls short of establishing the essence of body, as Descartes implies it does.

Finally let us turn to what I have called the complete concept argument. This argument is, in essence, found in the celebrated argument for the distinction between mind and body in the Sixth Meditation. But the premises of the argument are considerably clarified in the *Objections and Replies* and in correspondence of the period. Behind the argument is a certain view about the concepts we have. When we examine our concepts, we note that some of them are incomplete, and require certain connections to others for full comprehensibility. Writing to Gibieuf on 19 January 1642, Descartes noted:

> In order to know if my idea has been rendered incomplete or inadequate by some abstraction of my mind, I examine only if I haven't drawn it . . . from some other richer or more complete idea that I have in me through an abstraction of the intellect . . . Thus, when I consider a shape without thinking of the substance or the extension whose shape it is, I make a mental abstraction. . . . (AT III 474–5: CSMK 202)

And so Descartes noted in the Fourth Replies, in response to an objection of Arnauld's: "For example, we can easily understand the genus 'figure' without thinking of a circle. . . . But we cannot understand any specific differentia of the 'circle' without at the same time thinking about the genus 'figure' " (AT VII 223: CSM II 157).[34] Following out this series of conceptual dependencies, from circle to shape, we are led ultimately to the idea of a thing that has the appropriately general property, since, Descartes holds, "no act or accident can exist without a substance for it to belong to" (AT VII 175–6: CSM II 124).[35] When we examine our ideas, we find that all of the concepts we have sort themselves out into two classes, those that presuppose the notion of extension, and those that presuppose the notion of thought.[36] Answering Hobbes in the Third Replies Descartes wrote:

> Now, there are certain acts that we call 'corporeal', such as size, shape, motion and all others that cannot be thought of apart from local extension; and we use the term 'body' to refer to the substance in which they inhere. It

cannot be imagined [*fingi*] that one substance is the subject of shape, and another is the subject of local motion, etc., since all of those acts agree in the common concept [*communis ratio*] of extension. Next there are other acts which we call 'acts of thought', such as understanding, willing, imagining, sensing, etc.: these all agree in the common concept of thought or perception or consciousness [*conscientia*], and we call the substance in which they inhere a 'thinking thing', or a 'mind' . . . .

(AT VII 176: CSM II 124)[37]

And so, Descartes observes, again to Hobbes, "acts of thought have no relation to corporeal acts, and thought, which is their common concept, is altogether distinct from extension, which is the common concept of the other" (AT VII 176: CSM II 124). Thus, Descartes concludes, the ideas we have of mind and body do not depend upon one another for their conception. But, as Descartes argues in the Fourth Meditation, whatever we can clearly and distinctly conceive, God can create. And so, things purely extended can exist without thinking substance. The thinking things are what Descartes calls souls, or minds, and the extended substance from which they are distinguished in this argument is what Descartes calls body, or corporeal substance. Souls, or minds, contain sensation, intellection, and will, but extended substance contains the broadly geometrical properties of size, shape, and motion, and those alone; insofar as sensory qualities like heat and color presuppose thought and not extension, and thus require a thinking substance in which to inhere, Descartes claims, they belong not in extended substance but in mind and mind alone. And insofar as it is body so conceived that, we are inclined to believe, is the source of our sensory ideas of body, it is body so conceived that exists in the world, Descartes concludes. The bodies of physics are, thus, the objects of geometry made real.

4. BODY AND EXTENSION: SOME CONSEQUENCES

From the doctrine of body as extension, some extremely important consequences follow for Descartes about the physical world, doctrines that concern the impossibility of atoms and the void, as well as the falsity of the scholastic doctrine of substantial forms.

The void had been a topic much discussed for some centuries when Descartes turned to it in his system. Aristotle had clearly denied the possibility of a vaccum and empty space.[38] This raised

certain theological problems for Christian thinkers; as Etienne Tempier, bishop of Paris noted in his condemnation of various Aristotelian doctrines in 1277, were a vacuum impossible, then God could not move the world, should he desire to do so.[39] But despite the problems, later schoolmen continued to follow Aristotle in denying that there are empty spaces in the world, or that there could be. Indeed, the very idea of an empty space, a nothing that was something of a something, continued to be very puzzling to people well into the seventeenth century.[40] Though Descartes departed in many ways from the scholastic account of body, as we shall later see, he saw his identification of body and extension as leading him to the same conclusions that his teachers had reached, that the world is full and that there is no empty space.

While there is every reason to believe that Descartes had rejected the possibility of a vacuum as early as the late 1620s,[41] the strongest arguments for that view are found in his *Principles*. There Descartes appeals to the principle that every property requires a subject to argue that there can be no extension that is not the extension of a substance. Descartes writes:

> The impossibility of a vacuum, in the philosophical sense of that in which there is no substance whatsoever, is clear from the fact that there is no difference between the extension of a space, or internal place, and the extension of a body. For a body's being extended in length, breadth and depth in itself warrants the conclusion that it is a substance, since it is a complete contradiction that a particular extension should belong to nothing; and the same conclusion must be drawn with respect to a space that is supposed to be a vacuum, namely that since there is extension in it, there must necessarily be substance in it as well. (*Principles* Part II, art. 16)

And since, of course, extended substance is just body, it follows that the world must be full of body.

Descartes offers a graphic illustration of his position. He writes, again in the *Principles:*

> It is no less contradictory for us to conceive a mountain without a valley than it is for us to think of . . . this extension without a substance that is extended, since, as has often been said, no extension can belong to nothing. And thus, if anyone were to ask what would happen if God were to remove all body contained in a vessel and to permit nothing else to enter in the place of the body removed, we must respond that the sides of the vessel would, by

virtue of this, be mutually contiguous. For, when there is nothing between two bodies, they must necessarily touch. And it is obviously contradictory that they be distant, that is, that there be a distance between them but that that distance be a nothing, since all distance is a mode of extension, and thus cannot exist without an extended substance.

(*Principles* Part II, art. 18, Latin version)[42]

If the two sides of the vessel are separated, there must be some distance between them, and if there is distance, then there must be body. On the other hand, if there is no body, there can be no distance, and if there is no distance, then the two sides must touch.

In denying the possibility of a vacuum, Descartes rejected one of the central doctrines of the atomist tradition of Democritus, Epicurus, and Lucretius. Another central atomist doctrine fares little better on Descartes' conception of body. Important to the atomists was the view that the world of bodies is made up of indivisible and indestructable atoms. As Epicurus wrote:

Of bodies some are composite, others the elements of which these composite bodies are made. These elements are indivisible and unchangeable, and necessarily so, if things are not all to be destroyed and pass into nonexistence, but are to be strong enough to endure when the composite bodies are broken up, because they possess a solid nature and are incapable of being anywhere or anyhow dissolved. It follows that the first beginnings must be indivisible, corporeal entities.[43]

Atoms are, thus, indivisible, unchangeable bodies, the ultimate parts into which bodies can be divided and from which they can be constructed.

As with the void, Descartes seems to have rejected atoms from the late 1620s,[44] and filled the universe with a subtle matter that is infinitely divisible and, in some circumstances, infinitely or at least indefinitely divided.[45] Descartes' most careful argument against the possibility of an atom appears, again, in the *Principles*. Descartes writes:

We also know that there can be no atoms, that is, parts of matter by their nature indivisible. For if there were such things, they would necessarily have to be extended, however small we imagine them to be, and hence we could in our thought divide each of them into two or more smaller ones, and thus we could know that they are divisible. For we cannot divide anything in thought without by this very fact knowing that they are divisible. And therefore, if we were to judge that a given thing were indivisible, our judgment would be opposed to what we know. But even if we were to imagine that God wanted to have brought it about that some particles of matter not be divisible into smaller parts, even then they shouldn't properly be called indivisible. For indeed, even if he had made something that could not be divided by any creatures, he certainly could not have deprived himself of the ability to divide it, since he certainly could not diminish his own power. . . . And therefore, that divisibility will remain, strictly speaking, since it is divisible by its nature. (*Principles* Part II, art. 20)[46]

It is, then, the infinite divisibility of geometrical extension together with divine omnipotence that undermines atomism, Descartes argues. But such an argument, in an important way, misses the mark. While it may work for ancient versions of atomism which deny a transcendent and omnipotent God,[47] it will not work against the Christian atomists among Descartes' contemporaries, like Pierre Gassendi, who believed in an omnipotent God who was surely capable of splitting even an atom, if he chose to do so.[48] What is at issue for the atomists is *natural* indivisibility, not the possibility of *supernautral* divisibility.

But despite these significant departures from atomist doctrine, Descartes still shared their mechanist view of explanation; since all there is in body is extension, the world is made up of the same kind of stuff and everything must be explicable in terms of size, shape, and motion. Descartes writes in the *Principles:* "I openly admit that I know of no other matter in corporeal things except that which is capable of division, shape, and motion in every way, which the geometers call quantity and which they take as the object of their demonstrations. And, I admit, I consider nothing in it except those divisions, shapes, and motions" (*Principles* Part II, art. 64).[49] And so, like the atomists, Descartes rejects the substantial forms of the schoolmen.

Though he often tried to hide or, at least, deemphasize his opposition to the philosophy of the schools,[50] Descartes offered numerous reasons for rejecting substantial forms. Sometimes he suggests that forms are to be rejected for considerations of parsimony; everything can be explained in terms of size, shape, and motion, and thus, there is no reason to posit them. Thus he writes in *The World:*

When it [i.e., fire] burns wood or some other such material, we can see with our own eyes that it removes the small parts of the wood and separates them

from one another, thus transforming the more subtle parts into fire, air, and smoke, and leaving the grossest parts as cinders. Let others [e.g., the philosophers of the schools] imagine in this wood, if they like, the form of fire, the quality of heat, and the action which burns it as separate things. But for me, afraid of deceiving myself if I assume anything more than is needed, I am content to conceive here only the movement of parts. (AT XI 7: CSM I 83)

Elsewhere he claims not to understand what a substantial form is supposed to be, calling it "a philosophical being unknown to me," and characterizing it as a chimera.[51] Elsewhere still he contrasts the fruitfulness of the mechanical philosophy with the sterility of the scholastic philosophy. In the *Letter to Voëtius* Descartes remarks: "the common philosophy which is taught in the schools and academies . . . is useless, as long experience has already shown, for no one has ever made any good use of primary matter, substantial forms, occult qualities and the like" (AT VIIIB 26).[52] All of these arguments show Descartes' clear opposition to the substantial forms that underly the natural philosophy of the schools. But, in a way, it is his very doctrine of body that most clearly and unambiguously marks his opposition to the philosophy of form and matter; it is no mystery why Descartes was loath to mention his identification of body and extension in the rather cautious *Discourse* and *Essays*. As I noted above, Descartes saw the Aristotelian substantial forms as impositions of mind onto matter. When we learn, through his philosophy, that mind and body are distinct, we discover that all of the ideas we thought we had of substantial forms and the like derive from the ideas we have of our own minds, and that they do not in any way pertain to body as such, which contains extension and extension alone.[53] In this way the Cartesian doctrine of the distinction between mind and body is intended not only to clarify the notion of the mind, but also that of the body.[54]

But as clear as Descartes' arguments seem to be, as convincing as they might have been to many of his contemporaries, and as influential as they might have been on the downfall of Aristotelian natural philosophy, there are certain deep weaknesses in the case Descartes presents against his teachers. Though he sometimes claims not to understand what a form is supposed to be, his mentalistic interpretation of the scholastic doctrine would seem to undermine that pose. And while he sometimes claims that everything in physics can be explained with only size, shape, and motion, and while he contrasts the fruitfulness of his own mechanical philosophy with that of the schools, even his most sympathetic modern reader must see more than a little bit of bravado in those claims. The fact is that Descartes' mechanical philosophy is considerably more promise than accomplishment, and, in the end, size, shape, and motion turned out to be considerably less fruitful than Descartes and his mechanist contemporaries had hoped. But most importantly, there is an embarrassing hole in the argument that is supposed to lead from the nature of body as extension to the denial of substantial forms. If we grant Descartes his arguments for the distinction between body and mind, and his characterization of both, we can agree that if there are forms, they must be tiny minds of a sort, distinct from the extended bodies whose behavior they are supposed to explain. But that by itself does not seem to eliminate forms, so far as I can see; the schoolman can just continue to claim that however Descartes wants us to conceive of them, they are still there. To make the case, Descartes must show not only that forms are tiny minds, but that outside of human (and, perhaps, angelic) minds, there are no minds at all. Descartes does address this question, though not in its full generality; he does attempt to show that one kind of form the schoolmen posited, the forms that constitute the souls of animals, do not exist.[55] But even here, in this special case, Descartes finally admits to Henry More, who pressed Descartes to admit animal souls and much more, that his arguments are just probable, and cannot establish with any certainly the impossibility of animal souls.[56] And as go animal souls, so goes the more general question of substantial forms.

5. MOTION

Motion is quite crucial to the Cartesian physics; all there is in body is extension, and the only way that bodies can be individuated from one another for Descartes is through motion. In this way, it is motion that determines the size and shape of individual bodies, and, thus, motion is the central explanatory principle in Descartes' physics.

Though it is central to his thought, Descartes resisted defining motion through much of his career. In the *Rules*, for example, Descartes held quite explicitly that motion is simply not definable. Mak-

ing fun of a standard scholastic definition of motion, Descartes writes:

> Indeed, doesn't it seem that anyone who says that motion, a thing well-known to all, is *the actuality of a thing in potentiality insofar as it is in potentiality* is putting forward magic words . . . ? For who understands these words? Who doesn't know what motion is? . . . Therefore, we must say that these things should never be explained by definitions of these sorts, lest we grasp complex things in place of a simple one. Rather, each and every one of us must intuit these things, distinguished from all other things, by the light of his own intelligence [*ingenium*]. (AT X 426–7: CSM I 49)

This attitude is found also in the *The World*, and seems to continue throughout the 1630s.[57] But even though Descartes avoids formal definition, it is reasonably clear what he thinks motion is. In *The World*, for example, the motion we all immediately understand without benefit of definition is claimed to be: "that by virtue of which bodies pass from one place to another and successively occupy all of the spaces in between" (AT XI 40: CSM I 94).[58] Motion as Descartes understands it is, quite simply, local motion, the change of place, the motion of the geometers.

Behind these remarks is, again, an attack on the natural philosophy of his teachers. For the schoolmen, motion is a general term that embraces all varieties of change. As Descartes notes in *The World*: "The philosophers . . . posit many motions which they think can take place without any body's changing place, like those they call *motus ad formam, motus ad calorem, motus ad quantitatem* ('motion with respect to form', 'motion with respect to heat', 'motion with respect to quantity') and numerous others" (AT XI 39: CSM I 94). It is because of the generality of the notion of motion which they require that the schoolmen offer the very general definition of motion that Descartes is so fond of mocking, the definition of motion as the actuality of a thing in potentiality insofar as it is in potentiality. Motion conceived of in this very general way is the process of passing from one state (actuality) into another state that a body has potentially but not yet actually, from red to blue, from hot to cold, from square to round. But if Descartes is right, and all body is just extension, than all change must ultimately be grounded in change of place. And so for the obscure and paradoxical definition of change that the schoolmen offer us in their account of motion, Descartes substitutes the apparently clear and distinct notion of local motion, the motion of the geometers that we can all intuit without aid of definition.

But later, while writing the *Principles* and attempting to systemetize his thought, even the apparently clear geometric conception of local motion comes in for more careful scrutiny and formal definition. Descartes begins the account of the notion of motion in the *Principles* with a definition that is intended to capture the notion of motion as understood by the vulgar: "Motion . . . as commonly understood is nothing but the action [*actio*] by which some body passes [*migrat*] from one place into another" (*Principles* Part II, art. 24). In contrast to this, Descartes offers another definition that is supposed to capture the true notion of motion:

> But if we consider what we should understand by motion not so much as it is commonly used but, rather, in accordance with the truth of the matter, then in order to attribute some determinate nature to it we can say that it is the transference [*translatio*] of one part of matter or of one body from the neighborhood of those bodies that immediately touch it and are regarded as being at rest, and into the neighborhood of others.
>
> (*Principles* Part II, art. 25)

The positive definition that Descartes offers here is a very curious one, and in its almost baroque complexity many commentators have seen the shadow of the condemnation of Galileo.[59] But whatever external factors may have been at work in these passages, one can make reasonably good sense of what Descartes had in mind in his definition, and why he chose to define motion differently than the vulgar do.

The first important difference between Descartes and the vulgar concerns the notion of activity. According to the vulgar definition, motion is an action, an *actio*, while in the proper definition it is a transference, a *translatio*.[60] Descartes offers two different reasons for this difference. For one, if we think of motion as an action, then we are immediately led to think of rest as the *lack* of action, as Descartes notes in connection with the vulgar definition: "Insofar as we commonly think that there is action in every motion, we think that in rest there is a cessation of action . . ." (*Principles* Part II, art. 24). This, Descartes thinks, is a mistake, one of the many prejudices we acquire in our youth.[61] On the contrary, Descartes thinks, "No more

action is required for motion than for rest" (*Principles* Part II, art. 26). And so, Descartes argues, the action necessary to put a body at rest into motion is no greater than the activity necessary to stop it; rest requires as much of an active cause as motion does.[62] But there is another reason why Descartes prefers transference to action. Descartes writes in the *Principles:*

> And I say that [motion] is *transference*, not the force or action that transfers in order to show that it is always in the mobile thing, and not in what is moving it, since these two things are not usually distinguished carefully enough, and to show that [motion] is a mode of a thing, and not some subsisting thing, in just the same way as shape is a mode of a thing with shape, and rest is a mode of a thing at rest. (*Principles* Part II, art. 25)[63]

It is important for Descartes to distinguish motion, a mode of body, from its cause, that which puts the body in motion, which, as we shall later see, is God, in the general case in physics.

There is another important difference between the two definitions worth noting. The vulgar definition is given in terms of the change of place, while the proper definition talks of a body passing from one neighborhood, considered at rest, and into another. This difference is connected with the obvious fact that the designation of a place is relative to an arbitrarily chosen frame of reference, and so, it is only relative to this arbitrarily chosen frame that one can say that a body is or is not changing place. Descartes writes in explanation of the vulgar definition:

> the same thing can at a given time be said both to change its place and not to change its place, and so the same thing can be said to be moved and not to be moved. For example, someone sitting in a boat while it is casting off from port thinks that he is moving if he looks back at the shore and considers it as motionless, but not if he looks at the boat itself, among whose parts he always retains the same situation. (*Principles* Part II, art. 24)[64]

And so, on the vulgar definition of motion as change of place, there is no real fact of the matter about whether or not a given body is in motion; it all depends upon the arbitrary choice of a rest frame. Descartes' intention is that his proper definition will not have this undesirable feature. He writes in the *Principles:*

> Furthermore, I added that the transference take place *from the neighborhood of those bodies that immediately touch it into the neighborhood of others*, and not from one place into another since . . . the designation [*acceptio*] of place differs and depends upon our thought. But when we understand by motion that transference which there is from the neighborhood of contiguous bodies, since only one group of bodies can be contiguous to the mobile body at a given time, we cannot attribute many motions to a given mobile body at a given time, but only one. (*Principles* Part II, art. 28)

As Descartes notes on a number of occasions, motion and rest are opposites, and, he thought, the proper definition of motion must capture this fact.[65] But even though it is clear *that* Descartes wants to eliminate the arbitrariness in the distinction between rest and motion, it is not altogether clear *why* he wants to do so, or *how* he thinks the definition has this consequence.

As for the "why", though Descartes never says anything directly about this, it is not difficult to see why, in the Cartesian physics, one would want there to be a genuine distinction between motion and rest. As I noted earlier, motion is a basic explanatory notion in Descartes' physics: "all variation in matter, that is, all the diversity of its forms depends on motion" (*Principles* Part II, art. 23). But if the distinction between motion and rest is just arbitrary, a matter of an arbitrary choice of a rest frame, as it is on the vulgar definition, then it is difficult to see how motion could fulfill this function. Or, at least, this is the way I think Descartes thought about it. Later physicists, most notably Huygens, were able to figure out how to accommodate a radically relativistic notion of motion into a physics, but, I think, for Descartes, if there is no nonarbitrary distinction between motion and rest, then motion isn't really real, and if it isn't really real, then it cannot occupy the place he sets for it in his physics.

The 'how' is a bit more difficult to see. Descartes writes:

> If someone walking on a boat carries a watch in his pocket, the wheels of the watch move with only one motion proper to them, but they also participate in another, insofar as they are joined to the walking man and together with him compose one part of matter. They also participate in another insofar as they are joined to the vessel bobbing on the sea, and in another insofar as they are joined to the sea itself, and, finally, to another insofar as they are joined to the Earth itself, if, indeed, the Earth as a whole moves. And all of these motions are really in these wheels. (*Principles* Part II, art. 31)

But on the proper definition, of course, this cannot be said; since a body has only one immediately contiguous neighborhood it has at

most one proper motion. As Descartes puts it: "every body has only one motion proper to it, since it is understood to recede from only one [group of] contiguous and resting bodies" (*Principles* Part II, art. 31). This certainly eliminates some of the arbitrariness in the notion of motion; because a wheel of the watch is in motion with respect to its contiguous neighborhood, we are obligated to say that it is in motion, despite the fact that the watch as a whole is resting in the pocket of its owner. But, of course, this isn't the whole story. There are, of course, considerable difficulties in specifying exactly what the contiguous neighborhood of a given body is. But that aside, there is another obvious problem. Motion, Descartes says, is transference. But Descartes also acknowledges in the *Principles* that transference is reciprocal:

> Finally, I added that the transference take place from the neighborhood not of any contiguous bodies, but only from the neighborhood of those *regarded as being at rest*. For that transference is reciprocal, and we cannot understand body AB transferred from the neighborhood of body CD unless at the same time body CD is also transferred from the neighborhood of body AB. . . . Everything that is real and positive in moving bodies, that on account of which they are said to move is also found in the other bodies contiguous to them, which, however, are only regarded as being at rest.
> (*Principles*, Part II, arts. 29, 30)

And so, while there may be a sense in which a given body has only one proper motion, it would still seem to be an arbitrary decision whether to say that body AB is in motion and its neighborhood CD is at rest, or vice versa.

The doctrine of the reciprocity of transference has convinced many that Descartes' conception of motion does not allow for a genuine distinction between motion and rest.[66] But I think that this is a misunderstanding.

Crucial to understanding what Descartes had in mind is a little-known text, most likely a marginal note he wrote in his copy of the *Principles* in the mid-1640s, while the Latin edition of 1644 was being translated into French. The relevant portion reads as follows:

> Nothing is absolute in motion except the mutual separation of two moving bodies. Moreover, that one of the bodies is said to move, and the other to be at rest is relative, and depends on our conception, as is the case with respect to the motion called local. Thus when I walk on the Earth, whatever is absolute or real and positive in that motion consists in the separation of the surface of my foot from the surface of the Earth, which is no less in the Earth than in me. It was in this sense that I said that there is nothing real and positive in motion which is not in rest.[67] When, however, I said that motion and rest are contrary, I understood this with respect to a single body, which is in contrary modes when its surface is separated from another body and when it is not. . . . Motion and rest differ truly and modally [*modaliter*] if by motion is understood the mutual separation of bodies and by rest the lack [*negatio*] of this separation. However, when one of two bodies which are separating mutually is said to move, and the other to be at rest, in this sense motion and rest differ only in reason [*ratione*]. (AT XI 656–7)

This commentary on the sections of the *Principles* we have been examining suggests that there is, indeed, a sense in which the distinction between motion and rest is purely arbitrary; when I lift my foot, it is in a sense correct to say both that my foot is moving and the Earth at rest, and that the Earth is moving while my foot is at rest. But this is not the only way to think about motion and rest, Descartes suggests. Motion can also be thought of as the mutual separation of a body and its neighborhood, and in this sense, there is a non-arbitrary distinction between motion and rest; if a body and its neighborhood are in mutual transference, no mere act of thought can change that and put them at rest. Because of the doctrine of the reciprocity of transference, whenever a body is in motion, we must say that its neighborhood is as well, properly speaking; a body AB cannot separate from its neighborhood CD without, at the same time, CD separating from AB. And so Descartes notes in the *Principles*: "*If we want to attribute to motion its altogether proper and non-relative nature [omnino propriam, & non ad aliud relatam, naturam]* we must say that when two contiguous bodies are transferred, one in one direction, and the other in another direction, and thus mutually separate, there is as much motion in the one as there is in the other" (*Principles* Part II, art. 29). This, indeed, is the main thrust of the doctrine of the reciprocity of transference, not to introduce relativity and undermine the distinction between motion and rest, but to emphasize that a motion properly speaking belongs equally to a body and its contiguous neighborhood. But this in no way undermines the kind of distinction between motion and rest that Descartes wants to draw. If motion is understood as the mutual separation of a body and its neighborhood, then it is impossible for a body to be both in motion and at rest at the same time

insofar as it is impossible for that body both to be in transference and not in transference with respect to the same contiguous neighborhood. Understood in this way, motion and rest are different and distinct modes of body.[68]

Though Descartes' proper definition of motion thus allows us to draw a non-arbitrary distinction between motion and rest, the distinction comes at some cost, and results in a conception of motion that is not altogether appropriate to the physics that he wants to build on it. On the vulgar conception of motion as change of place, notions like speed and direction are well-defined, given the choice of a rest frame. But matters are not so clear on Descartes' preferred definition. As a body moves in the plenum, its neighborhood of contiguous bodies will change from moment to moment, and without a common frame of reference, it is not clear what sense can be made of the notions of direction and speed, basic to Descartes' mechanist physics. There is no reason to believe that Descartes saw the problems that his definition raised. My suspicion is that it was work in progress (as other aspects of his physics were), an attempt to deal with a serious problem in the foundations of his natural philosophy that had not yet been fully integrated into his full system. It is significant that when we turn to his laws of motion later in this chapter, we shall find Descartes implicitly depending not on the complex definition of motion that he puts forward, but on a conception of motion as change of place.

6. THE LAWS OF MOTION

There is one kind of body in Descartes' world, material substance whose essence is extension, and all of whose properties are modes of extension. But how does this substance behave? For the schoolmen, each kind of substance had its characteristic behavior, determined by its substantial form; water tends to be cool, fire hot, air tends to rise, and earth fall. Descartes, of course, cannot appeal to such characteristic behaviors. For him, the characteristic behavior of body as such, corporeal substance, is given by a series of laws of nature. Since, as noted above, all change is grounded in local motion, these laws of nature are, in essence, laws that govern the motion of bodies.

While there are numerous indications of Descartes' interest in the laws of motion from his earliest writings, the first attempt to present a coherent account of those laws is found in *The World*. Descartes begins his account in chapter 7 by turning directly to God. "It is easy to believe," Descartes says, "that God . . . is immutable, and always acts in the same way" (AT XI 38: CSM I 93). From this Descartes derives three laws in the following order:

> [Law A:] Each part of matter, taken by itself, always continues to be in the same state until collision [*recontre*] with others forces it to change. . . . [And so,] once it has begun to move, it will continue always with the same force, until others stop it or slow it down. (AT XI 38: CSM I 93)

> [Law B:] When a body pushes another, it cannot give it any motion without at the same time losing as much of its own, nor can it take any of the other's away except if its motion is increased by just as much. (AT XI 41: CSM I 94)

> [Law C:] When a body moves, even if its motion is most often on a curved path . . . , nevertheless, each of its parts, taken individually, always tends to continue its motion in a straight line. (AT XI 43–44: CSM I 96)

Hidden in the argument Descartes offers for the first two laws is another principle of some interest:

> Now, these two rules follow in an obvious way from this alone, that God is immutable, and acting always in the same way, he always produces the same effect. Thus, assuming that he had placed a certain quantity of motions in the totality of matter from the first instant that he had created it, we must admit that he always conserves in it just as much, or we would not believe that he always acts in the same way. (AT XI 43: CSM I 96)[69]

This, of course, is the principle of the conservation of quantity of motion, a principle that will play an explicit and important role in the later development of his laws of nature.

The laws Descartes formulated in *The World* and the basic strategy he used to prove them, by appeal to God, remained very much the same throughout his career. But when, in the early 1640s Descartes wrote the corresponding sections of the *Principles of Philosophy*, the laws took on a new and somewhat more coherent shape.

Prominent in the account of the laws Descartes gives in the *Principles* is a distinction not found in the earlier *World*. Descartes begins:

> Having taken note of the nature of motion, it is necessary to consider its cause, which is twofold: namely, first, the universal and primary cause, which is the general cause of all the motions there are in the world, and then

the particular cause, from which it happens that individual parts of matter acquire motion that they did not previously have.

(*Principles* Part II, art. 36)

Descartes characterizes the "universal and primary cause" as follows:

And as far as the general cause is concerned, it seems obvious to me that it is nothing but God himself, who created motion and rest in the beginning, and now, through his ordinary concourse alone preserves as much motion and rest in the whole as he placed there then. (*Principles* Part II, art. 36)

Though it is not explicitly identified as a law, Descartes goes immediately on to state a version of the same conservation principle introduced earlier in *The World:*

Whence it follows that is most in agreement with reason for us to think that from this fact alone, that God moved the parts of matter in different ways which he first created them, and now conserves the whole of that matter in the same way and with the same laws [*eademque ratione*] with which he created them earlier, he also always conserves it with the same amount of motion. (*Principles* Part II, art. 36)

After discussing the universal cause of motion, Descartes turns to the particular causes:

And from this same immutability of God, certain rules or laws of nature can be known, which are secondary and particular causes of the different motions we notice in individual bodies. (*Principles* Part II, art. 37)

Descartes then introduces three laws of motion, the recognizable successors of the laws he presented earlier in *The World*, though presented in a different order. The first law corresponds closely to law A of *The World:*

[Law 1:] Each and every thing, insofar as it is simple and undivided, always remains, insofar as it can [*quantum in se est*], in the same state, nor is it ever changed except by external causes. . . . And therefore we must conclude that whatever moves, always moves insofar as it can.

(*Principles* Part II, art. 37)[70]

The second law concerns rectilinear motion, and corresponds to law C of *The World:*

[Law 2:] Each and every part of matter, regarded by itself, never tends to continue moving in any curved lines, but only in accordance with straight lines. (*Principles* Part II, art. 39)

The third law pertains to collision, and it is a further development of Law B of *The World:*

[Law 3:] When a moving body comes upon another, if it has less force for proceding in a straight line than the other has to resist it, then it is deflected in another direction, and retaining its motion, changes only its determination. But if it has more, then it moves the other body with it, and gives the other as much of its motion as it itself loses. (*Principles* Part II, art. 40)

Law 3 is then followed by a series of seven rules in which Descartes works out the specific outcomes of various possible cases of direct collision.[71]

Let us begin our discussion by considering Descartes' conservation principle, as given in the *Principles*. When Descartes gives this principle in *The World*, as I noted earlier, it is not given as a principle, but as part of the argument for the collision law, Law B. Furthermore, there is no numerical measure suggested; Descartes characterizes what God conserves in the world merely as a "certain quantity of motions" (AT XI 43: CSM I 96). The phrase he uses, "*quantité de mouvements*," curiously enough in the plural, may be a typographical error, but it may indicate that what Descartes' God is preserving is, quite literally, a certain number of motions, perhaps the fact that such-and-such a number of bodies is moving.[72] However, it is also quite possible that Descartes was simply unclear about what precisely it was that God was conserving at this point. In the *Principles* though, Descartes is quite clear about the numerical measure. He writes:

Although . . . motion is nothing in moving matter but its mode, yet it has a certain and determinate quantity, which we can easily understand to be able to remain always the same in the whole universe of things, though it changes in its individual parts. And so, indeed, we might, for example, think that when one part of matter moves twice as fast as another, and the other is twice as large as the first, there is the same amount of motion in the smaller as in the larger. . . . (*Principles* Part II, art. 36)

What God conserves, Descartes suggests, is size times speed.

It is important here not to read into Descartes' conservation principle the modern notion of momentum, mass times velocity. First of all, Descartes and his contemporaries did not have a notion of mass independent of size; in a world in which all body is made up of the

same kind of stuff, there is no sense to equal volumes (without pores, etc.) containing different quantities of matter.[73] And while Descartes was certainly aware of the importance of considerations of directionality,[74] directionality does not enter into the conservation principle at all. What is conserved is size times speed *simpliciter*, so that when a body reflects, and changes its direction, then as long as there is no change in its speed, there is no change in the quantity of motion.[75]

Descartes' conservation principle was exteremely influential on later physicists; a basic constraint on nature, it defined an important way of thinking about how to do physics. Unfortunately, the law turned out to be radically wrong. Though many Cartesians were very resistant to admitting it, Descartes' conservation principle led to many absurdities. In an important series of arguments in the 1680s and 1690s, Leibniz displayed some of the absurdities that follow from Descartes' principle, including the fact that if the world were governed by Descartes' principle, one could construct a perpetual motion machine.[76]

But right or wrong, the conservation principle is not, by itself, sufficient for Cartesian physics. Though in the *Principles* it is presented as a general constraint on all motion, it does not, by itself, tell us how any individual bodies behave; as long as the *total* quantity of motion in the world is conserved the conservation principle is satisfied, no matter how any individual body may happen to behave. It is in this sense, I think, that the conservation principle is taken to be the "universal and primary" cause of motion, and must be supplemented with "secondary and particular causes," a series of particular laws that, like the conservation principle, are said to follow from the immutability of God. As given in the *Principles* these laws include two laws that might be called *principles of persistence*, laws that mandate the persistence of certain quantities in individual bodies, motion in the case of Law 1, and the tendency to move in a rectilinear path in the case of Law 2. But sometimes these laws may come into conflict in different bodies; if A is moving from right to left, it may encounter a body B that is moving from left to right. Laws 1 and 2 tell us that the motions of both bodies tend to persist; Law 3 tells us how the conflicting motions in those two bodies are reconciled with one another and in that sense, it constitutes a kind of *principle of reconciliation*.

Law 1 asserts that every thing remains in the state it is in, until changed by external causes. Motion apparently enters as a special case, something that is a state of body, and, as such, must persist in just the same way as other states of body. This principle is set in direct opposition to Aristotelian accounts of motion. On the Aristotelian conception of motion, a body in motion tends to come to rest. Elaborate explanations had to be given for why a projectile continues in motion after it leaves that which gives it its initial push.[77] Descartes, of course, does not have to explain this. He writes: "Indeed, our everyday experience of projectiles completely confirms this first rule of ours. For there is no other reason why a projectile should persist in motion for some time after it leaves the hand that threw it, except that what is once in motion continues to move until it is slowed down by bodies that are in the way" (*Principles* Part II, art. 38). The Aristotelian view that bodies in motion tend toward rest is, for Descartes, an absurdity. Descartes notes that those who except motion from the general principle of the persistence of states hold that: "[motions] cease of their own nature, or tend toward rest. But this is, indeed, greatly opposed to the laws of nature. For rest is contrary to motion, and nothing can, from its own nature, proceed toward its own contrary, or toward its own destruction" (*Principles* Part II, art. 37).[78] Two things are especially noteworthy here. First, unlike the schoolmen, Descartes sees motion as itself a state of body. For the schoolmen, motion is the process of passing from one state to another;[79] for Descartes, it is itself a state, and as such, it persists. Second, for Descartes it is a state that is distinct from and opposite to that of rest. Descartes seems unambiguous here in holding that motion and rest are opposites.

This observation, that motion in and of itself persists, is one of the most important insights that grounds the new physics of the seventeenth century. Descartes did not invent it; it can be found earlier in his mentor Isaac Beeckman, and in various forms in his contemporaries Galileo and Gassendi. It received its canonical statement in Sir Isaac Newton's *Principles*, where it is enshrined as the principle of inertia.[80] Descartes is sometimes given the credit for having the first published statement of the "correct" version of this important principle, and he may deserve it. However, it is important to recognize that while Descartes was certainly an early advocate of the principle, and important in disseminating it, it was very much in the air at

the time he was writing, and the version he offers, grounded as it is in the radical distinction between motion and rest, as we have seen, and in the immutability of God is in important ways different than the similar principle offered by others in his century.[81]

In the explicit statement of Law 1, Descartes is not clear about the motion that is said to persist; does it always maintain the same direction? the same speed? This is to some extent clarified by Law 2 of the *Principles*, which makes clear that what persists is rectilinear motion: "each and every part of matter, regarded by itself, never tends to continue moving in any curved lines, but only in accordance with straight lines" (*Principles* Part II, art. 39). But this law is more than just an amplification and clarification of Law 1. The real focus of Law 2 is an important consequence of the persistence of rectilinear motion, the tendency of a body in curvilinear motion to recede from the center of rotation. Consider a body rotating around a center, for example, a stone in a sling. If we consider all of the causes that determine its motion, then the stone "tends" (*tendere, tendre*) circularly.[82] But if we consider only "the force of motion it has in it" (*Principles* Part III, art. 57) then, Descartes claims, it "is in action to move," or "is inclined to go," or "is determined to move" or "tends" to move in a straight line, indeed, along the tangent to the circle at any given point.[83] And, Descartes concludes: "From this it follows that every body which is moved circularly tends to recede from the center of the circle that it describes" (*Principles* Part II, art. 39).[84] This tendency to recede, what later came to be called centrifugal force, is very important to Descartes' program in physics. Descartes held that the planets are carried around a central sun by a sworl of fluid, what he called a vortex. Light, on Descartes' view, is just the pressure that this fluid exerts in trying to recede from the center of rotation.[85] Law 2 is central to the program insofar as it establishes the existence of this centrifugal tendency that is light. Though, in a sense, it is just a consequence of the more general Law 1, it is sufficiently important to Descartes to get independent statement.

The third and last law in the *Principles* governs what happens in impact, when two bodies have states, both of which would tend to persist, but which cannot persist at the same time. The question was certainly broached in Law B of *The World*. There Descartes writes that "when a body pushes another, it cannot give it any motion without at the same time losing as much of its own, nor can it take

any of the other's away except if its motion is increased by just as much" (AT X 41: CSM I 94). But although this bears on the question of impact, it falls considerably short of a genuine law of impact. The law says that if one body transfers motion to another in collision, it must lose a corresponding amount of its own. But it does not say when motion is to be transfered, and when it is, exactly how much one body gives to another. And so, from this law it is impossible to determine the actual outcome of an actual collision. Matters are a bit clearer with the impact law Descartes presents in the *Principles*. There Descartes divides the question into two cases. Consider body B colliding with body C. If B has less force for proceeding than C has force of resisting, then B is reflected, and C continues in its previous state. But if B has more force for proceeding than C has force of resisting, then B can move C, giving it as much motion as it loses. Impact, then, is regarded as a kind of contest between the two bodies. If the force for proceeding in B is less than the force of resisting in C, then C wins and gets to keep its state. If, on the other hand, the force for proceeding in B is greater than the force of resisting in C, then B wins and gets to impose its motion on C.[86]

Although the impact law in the *Principles* is a considerable advance over the parallel law in *The World*, it is still not clear how exactly it is to be applied in actual circumstances; it is by no means clear from the bare law just how force for proceeding and force of resisting are to be calculated, and how much motion is to be transfered from the winner to the loser of the contest, for example. But matters are clarified a bit through an example that Descartes works out in the *Principles*. Immediately following the statement of Law 3 (and some explanitory remarks) Descartes adds seven rules of impact, dealing with various possible cases in which two bodies moving on the same line collide directly. (The rules are summarized in the Appendix to this chapter.) From the rules Descartes gives we can infer much about how he was thinking about impact. From R1–R3, for example, we can conclude that when we are dealing with two bodies in motion, their force for proceeding and force of resisting is simply to be measured by their quantity of motion, that is, their size times their speed. Furthermore, from R2 and R3 we can also infer that when a body B wins the impact contest, it imposes just enough motion on C to enable B to continue in the same direction in which it was moving, that is, just enough motion for B and C to be able to

move off in the same direction with the same speed. The cases in which one body is at rest is a bit more complex. Consider R4–R6. It is fair to assume, I think, that as in R1–R3, the force for proceeding in B is measured by B's size times its speed. But what of the force of resisting in C? In presenting these cases, Descartes argues that "a resting body resists a greater speed more than it does a smaller one, and this in proportion to the excess of the one over the other" (*Principles* Part II, art. 49). This suggests that the force of resisting C exerts is proportional to its own size, and the speed of the body that is colliding with it. This has the rather strange consequence (which Descartes fully endorsed) that a larger body at rest could never be moved by a smaller body in motion, no matter how fast that smaller body were to move.[87]

Descartes' seven rules of impact were very problematic for his contemporaries. Descartes found very quickly that he had to explain himself at some length, particularly with respect to his analysis of the case in which one body is at rest, and in the French edition of the *Principles* of 1647, these sections receive alterations more extensive than those in any other section in the book.[88] Indeed, the law of impact and the rules that follow seem to be work in progress that Descartes never really finished. Nor for that matter are they ever applied to any real problems in Descartes' physics. As late as 26 February 1649, Descartes wrote Chanut saying that "one need not" spend much time with the rules of impact, because "they are not necessary for understanding the rest" of the *Principles* (AT V 291: CSMK 369).

Later physicists quite decisively rejected Descartes' rather crude formulations.[89] But despite the obvious problems there are with the rules, they are very revealing of certain aspects of Descartes' thought. For one, the rules of impact show quite clearly Descartes' distinction between motion and rest. Consider rules R5 and R6, the case in which two unequal bodies collide, one of which is at rest. When the larger body is at rest, the smaller one is reflected (R5), but when the smaller body is at rest, both travel off at the same speed in the same direction (R6). These two cases clearly cannot be redescriptions of one another. But if the distinction between motion and rest is just arbitrary, then it should make no physical difference whether it is the smaller or larger body that we consider at rest. But even though the rules of impact embody the nonarbitrary distinction Descartes wants to draw between motion and rest, there is no hint in the rules of impact of the complex definition of motion that is supposed to enable us to draw the distinction.[90] In the rules of impact, there is no reference to the presumably separate neighborhoods of bodies assumed at rest in terms of which the proper motions of bodies B and C are defined. A common frame of reference is assumed; motion is treated almost as if it were simple local motion.

7. MOTION AND FORCE

One question that the laws of impact raise for the Cartesian metaphysics is that of force. As we discussed at some length above, for Descartes, bodies are extension and extension alone, and contain only the modes of extension. But we also saw that in Law 3 of the *Principles*, Descartes makes explicit appeal to the notion of force, the force for proceeding and the force of resisting bodies have, that, Descartes holds, determines the outcome of any collision. What sense can be made of the claim that merely extended bodies have such forces? In explicating Law 3, Descartes offers the following account of the forces to which that law appeals:

> *What the force each body has to act or resist consists in.* Here we must carefully note that the force each body has to act on another or to resist the action of another consists in this one thing, that each and every thing tends, insofar as it can (*quantum in se est*) to remain in the same state in which it is, in accordance with the law posited in the first place.[91] Hence that which is joined to something else has some force to impede its being separated; that which is apart has some force for remaining separated; that which is at rest has some force for remaining at rest, and as a consequence has some force for resisting all those things which can change that; that which moves has some force for persevering in its motion, that is, in a motion with the same speed and toward the same direction. (*Principles* Part II, art. 43)

Because bodies remain in their states of rest or motion in a particular direction with a particular speed, they exert forces that keep them in their states, and resist change, Descartes claims.[92] But this answer is not wholly satisfactory; for it just raises the question as to how Cartesian bodies can have the tendencies that Descartes attributes to them, a notion no less problematic than that of force.

A satisfactory answer to these questions leads us back to the ultimate ground of the laws of motion, God. As noted above, Descartes

is quite explicit in holding that it is God who grounds the laws of motion in the world. Descartes, along with the tradition in Christian thought, holds that God must not only create the world, but he must also sustain the world he creates from moment to moment.[93] It is this conception of God that is explicitly introduced in justifying the conservation principle that starts the exposition of the laws in the *Principles*.

> We also understand that there is perfection in God not only because he is in himself immutable, but also because he works in the most constant and immutable way. Therefore, with the exception of those changes which evident experience or divine revelation render certain, and which we perceive or believe happen without any change in the creator, we should suppose no other changes in his works, so as not to argue for an inconstancy in him. From this it follows that it is most in harmony with reason for us to think that merely from the fact that God moved the parts of matter in different ways when he first created them, and now conserves the totality of that matter in the same way and with the same laws [*eademque ratione*] with which he created them earlier, he always conserves the same amount of motion in it. (*Principles* Part II, art. 36)

Descartes similarly appeals to the divine sustenance in justifying his "secondary and particular causes" of motion, the three laws that follow the initial conservation principle: "From God's immutability we can also know certain rules or laws of nature, which are the secondary and particular causes of the various motions we see in particular bodies" (*Principles* Part II, art. 37). Descartes' reasoning is by no means clear here, and there is wide lattitude for interpretation. But one way or another Descartes held that it is an immutable God whose divine sustenance is responsible for the various laws Descartes posits, for the conservation of quantity of motion, for the persistence of motion, for the orderly exchange of motion in collision.

This suggests that the force Descartes appeals to in Law 3, and the tendency a body has to persevere in its state derive from God, from the immutable way in which he sustains the world he creates, in particular, from the way in which he sustains the bodies in motion in that world. In this way force is not *in* bodies themselves.[94]

The appeal to divine conservation that underlies the laws of motion in Descartes' physics suggests strongly that in the physical world, at least, it is God who is the primary cause of motion; in a

world without the substantial forms of the schoolmen to do the job, God steps in directly to cause bodies to behave as they characteristically do. This comes out nicely in an exchange that Descartes had with Henry More. Writing to Descartes on 5 March 1649, More asked if "matter, whether we imagine it to be eternal or created yesterday, left to itself, and receiving no impulse from anything else, would move or be at rest?" (AT V 316)[95] Descartes' answer appears in August 1649: "I consider 'matter left to itself and receiving no impulse from anything else' as plainly being at rest. But it is impelled by God, conserving the same amount of motion or transference in it as he put there from the first" (AT V 404: CSMK 381). God, Descartes suggests, is what causes bodies to move in the physical world. But God is not the only cause of motion *in* Descartes' world.

But even though God is the primary cause of motion in the physical world, it is important to recognize that God is not the only such cause; Descartes does allow that finite minds, too, can move bodies. Writing again to More, Descartes notes:

> That transference that I call motion is a thing of no less entity than shape is, namely, it is a mode in body. However the force [*vis*] moving a [body] can be that of God conserving as much transference in matter as he placed in it at the first moment of creation or also that of a created substance, like our mind, or something else to which [God] gave the power [*vis*] of moving a body. (AT V 403–4: CSMK 381)

What is that "something else" Descartes has in mind here? Angels are certainly included, as certain other passages in the More correspondence and elsewhere suggest.[96] It is not *absolutely* impossible that Descartes meant to include bodies among the finite substances that can cause motion.[97] But I think that it is highly unlikely. If Descartes really thought that bodies could be causes of motion like God, us, and probably angels, I suspect that he would have included them *explicitly* in the answer to More; if bodies could be genuine causes of motion, this would be too important a fact to pass unmentioned. Furthermore, Descartes' whole strategy for deriving the laws of motion from the immutability of God presupposes that God is the real cause of motion and change of motion in the inanimate world of bodies knocking up against one another. Somewhat more difficult to determine is whether or not bodies can be genuine causes of the states of sensation or imagination. Though Descartes persists in

holding that mind can cause motion in bodies, he is somewhat more guarded about the causal link in the opposite direction. The argument for the existence of the external world presented in the Sixth Meditation, where bodies are said to contain the "active faculty" that causes sensory ideas in us would suggest that bodies are the real causes of our sensations. But later versions of the argument found in the Latin and French versions of the *Principles* don't make use of the notion of an active faculty in bodies, and seem to posit a progressively weaker conception of the relation between bodies and the sensory ideas that we have of them.[98] While there is room for disagreement, it seems to me that all of the important signs lead to the view that bodies (inanimate bodies, at least) have no real causal efficacy, and lack the ability to cause either changes in motion in other bodies, or sensations in minds.

With the account of the laws of motion, we complete the foundations of Descartes' program for physics. Though I shall end my account here, Descartes did not. Descartes' program extended to the explanation of all phenomena in the physical world, life included, all grounded on the simple foundations he set out, extended substance, moving in accordance with the laws of motion.[99]

APPENDIX: DESCARTES' IMPACT RULES
PRINCIPLES PART II, ARTS. 46–52

Consider bodies B and C, where v(B) and v(C) are the speeds B and C have before impact, v(B)' and v(C)' are their speeds after impact, and m(B) and m(C) are their respective sizes.

Case I: B is moving from right to left, and C is moving from left to right

R1. If m(B)=m(C), and v(B)=v(C), then after the collision, v(B)'=v(C)'=v(B)=v(C), B moves from left to right, and C moves from right to left (i.e, B and C are reflected in opposite directions). (art. 46)

R2. If m(B) > m(C), and v(B)=v(C), then after the collision, v(B)'=v(C)'=v(B)=v(C), B and C move together from left to right (i.e., B continues its motion and C is reflected in the opposite direction). (art. 47)

R3. If m(B)=m(C), and v(B) > v(C), then after the collision, B and C move together from right to left (i.e., B continues its motion and C is reflected in the opposite direction) and v(B)'=v(C)'={[v(B)+v(C)]/2}. (art. 48)

Case II: C is at rest and B collides with it

R4. If m(B) < m(C), then after the collision, C remains at rest and B rebounds (i.e., B moves off in the opposite direction) with v(B)'=v(B). (art. 49)

R5. If m(B) > m(C), then after the collision, B and C move together in the direction in which B was moving before the collision, with v(B)'=v(C)'={m(B)v(B)/[m(B)+m(C)]}. [The formula is inferred from the example using the conservation principle.] (art. 50)

R6. If m(B)=m(C), then after the collision, C moves in the direction B originally moved with v(C)'={1/4}v(B) and B would be reflected in the opposite direction, with v(B)'={3/4}v(B). (art. 51)

Case III: B and C move in the same direction, with v(B) > v(C)

R7a. If m(B) < m(C) and "the excess of speed in B is greater than the excess of size in C," i.e., v(B)/v(C) > m(C)/m(B), then after the collision, B transfers to C enough motion for both to be able to move equally fast and in the same direction. I.e., v(B)'=v(C)'={m(B)v(B)+m(C)v(C)]/[m(B)+m(C)]. [The formula is inferred from the example using the conservation principle. In the French version, Descartes drops the condition that m(B) < m(C), though he keeps the condition that v(B)/v(C) > m(C)/m(B).] (art. 52)

R7b. If m(B) < m(C) and "the excess of speed in B" is less than "the excess of size in C," i.e., v(B)/v(C) < m(C)/m(B), then after the collision, B is reflected in the opposite direction, retaining all of its motion, and C continues moving in the same direction as before, with v(B)=v(B)' and v(C)=v(C)'. (art. 52)

R7c. If m(B) < m(C) and v(B)/v(C)=m(C)/m(B), then B transfers "one part of its motion to the other" and rebounds with the rest. [This rule is only in the French edition. There is no example from which one can infer a formula, but perhaps Descartes means that B

would transfer half of its speed to C, so that by the conservation principle, v(B)' = v(B)/2 and v(C)' = (3/2v(C).] (art. 52, French version)

NOTES

1 For accounts of medieval natural philosophy, see, for example, Grant, *Physical Science in the Middle Ages*; Lindberg, (ed.), *Science in the Middle Ages*; Kretzmann, et al., (eds.), *The Cambridge History of Later Medieval Philosophy*, sect. VII.

2 For an overview of Renaissance alternatives to Aristotelianism in natural philosophy, see, for example, Ingegno, "The new philosophy of nature," in Schmitt, et al. (eds.), *The Cambridge History of Renaissance Philosophy*, pp. 236–63. It is to be emphasized that in the Renaissance there was not one single opposition to Aristotle and Aristotelianism, but a wide variety of quite different opposing programs.

3 On the persistence of Aristotelianism in the Renaissance and into the seventeenth century, see especially Schmitt, *Aristotle and the Renaissance*. For an account of the sort of education Descartes would have received in the Jesuit schools, see the notes to part one in Gilson, *Descartes: Discours de la méthode, texte et commentaire*, and C. de Rochemonteix, *Un collège des Jésuites* . . . The Jesuit schools of the time were supposed to follow the Jesuit *Ratio Studiorum*, a careful and detailed curriculum that had been worked out and approved by the Society of Jesus for use in their schools. See, for example, Fitzpatrick (ed.), *St. Ignatius and the Ratio Studiorum*. The full text of the *Ratio Studiorum* is given in Ladislaus Lukács, S.J., (ed.), *Ratio atque Institutio Studiorum Societatis Iesu. (1586, 1591, 1599)* (*Monumenta Paedagogica Societatis Iesu*, vol. V; *Monumenta Historica Societatis Iesu* . . . , vol. 129] (Rome: Institutum Historicum Societatis Iesu, 1986). For a more general account of French higher education in the period, see Brockliss, *French Higher Education in the Seventeenth and Eighteenth Centuries*.

4 See, for example, Aristotle, *Physics* I, ch. 7, particularly as interpreted in St. Thomas, *The Principles of Nature*. In practice, though, the theory could get very complex. See, for example, Maier, *On the Threshold of Exact Science*, pp. 124–42.

5 For St. Thomas, for example, substantial form is that which actualizes prime matter, and matter by itself is pure potentiality; see *On Being and Essence*, chap. 2. For other later thinkers, though, form and matter have greater autonomy from one another, and more of a capacity for independent existence. See, for example, Whippel, "Essence and Existence," in Kretzmann, et al. (eds.), pp. 385–410, esp. p. 410.

6 See also AT III 667; CSMK 219; AT V 222–23; CSMK 357–8. Descartes offers a similar interpretation of Roberval, who had proposed a kind of theory of universal gravitation; see AT IV 401. While I often borrow from the excellent translations in CSM, in most cases the translations are my own, for better or for worse.

7 See the reference cited in note 2, and Vickers (ed.), *Occult and Scientific Mentalities in the Renaissance*.

8 On seventeenth-century atomism, see especially Lasswitz, *Geschichte der Atomistik vom Mittelalter bis Newton*; Kargon, *Atomism in England from Hariot to Newton*; Marie Boas, "The establishment of the mechanical philosophy," *Osiris* 10 (1952), pp. 412–541; Jones, *Pierre Gassendi 1592–1655: An Intellectual Biography*; Joy, *Gassendi the Atomist: Advocate of History in an Age of Science*; and Meinel, "Early Seventeenth-Century Atomism: Theory, Epistemology, and the Insufficiency of Experiment."

9 Though he was later to reject the physics he had been taught, it is interesting that when in 1638 a friend asked where he should send his son for schooling, he recommended not the Dutch universities, where there were many sympathetic to Descartes' own thought, but La Flèche, singling out the teaching of philosophy for special praise. See AT II 378.

10 On the teaching of mathematics in the Jesuit schools, see Cosentino, "Le matematiche nella *Ratio Studiorum* della Compagnia di Gesù," pp. 171–213; Dainville, "L'ensegnement des mathématiques dans les Collèges Jésuites de France du XVI[e] au XVIII[e] siècle," pp. 6–21, 109–23; Rodis-Lewis, "Descartes et les mathématiques au collège," in Grimaldi and Marion (eds.), *Le Discours et sa méthode*, pp. 187–211; Wallace, *Galileo and his Sources: The Heritage of the College Romano in Galileo's Science*, pp. 136–48; and Dear, *Mersenne and the Learning of the Schools*, chap. 4.

11 Beeckman's complete surviving notes are published in de Waard (ed.), *Journal tenu par Isaac Beeckman de 1604 à 1634*; the passages that relate specifically to Descartes can be found in AT X 41–78. Descartes' own record of some of those conversations can be found in the notes from Descartes' "Parnasus" manuscript, as preserved by Leibniz; see AT X 219ff and Gouhier, *Les Premières Pensées de Descartes*, p. 15. It is from this period that Descartes' first completed work dates, the *Compendium musicae*, written by Descartes as a present for Beeckman. The *Compendium* can be found in AT X 88–141 and in a new, annotated edition by Frédéric de Buzon. The study of music was, of course, for Descartes' contemporaries, part of mixed mathematics, along with astronomy and mechanics, and so this work fits neatly within the context of the other things Descartes discussed with his mentor. On the place of

music in early seventeenth-century thought, see Dear, *Mersenne and the Learning of the Schools*, chap. 6.

12 In one of the discussion notes Descartes presented to Beeckman, he talks of "one atom of water [*unus aquae atomus*]" traveling twice as fast as "two other atoms"; see AT X 68. Furthermore, the problems Descartes discussed with Beeckman include the problem of free-fall in a vacuum; see AT X 58–61, 75–8. While suggestive, these are not decisive. Though Descartes used the term "atom," it is not in a context in which its indivisibility or perfect hardness is at issue, so it isn't clear that he meant the term in its strict technical usage. Furthermore, the [counterfactual] discussion of motion in a vacuum is commonplace among scholastic natural philosophers, all of whom would deny that there really could be such vacua in nature.

13 On Descartes' development in the 1620s, see Milhaud, *Descartes savant*; Rodis-Lewis, *L'Oeuvre de Descartes*, ch. II. For the dating and development of the *Rules* see Weber, *La Constitution du texte des Regulae*; and Schuster, "Descartes' *Mathesis universalis*, 1619–28," in Gaukroger [ed.], *Descartes: Philosophy, Mathematics and Physics*, pp. 41–96.

14 Magnetism is discussed in Rules XII, XIII, and XIV of the *Rules*: AT X 427, 430–1, 439: CSM I 49–50, 52, 57.

15 See particularly Rules XII and XIV of the *Rules*. AT X 419, 442–7: CSM I 44–5, 59–62.

16 The metaphysics of 1629–30 is mentioned in a letter to Mersenne: 15 April 1630, AT I 144: CSMK 22. For an account of what it might have contained, see Rodis-Lewis, *L'Oeuvre*, ch. III.

17 See, for example, AT I 13, 23, 53f, 71, 106–7, 109, 119–20, 127, 179.

18 See AT I 270–2, 285–6; the latter is translated in CSMK 42–4.

19 See AT I 314, 339; the latter is translated in CSMK 50–2. The former passage, from a letter to Morin from September or October 1634 is not altogether clear, but the implication is that Descartes may be back to work on his *Optics*.

20 See AT VI 74–77: CSM I 149–50.

21 See AT III 232–3: CSMK 156 and AT III 259–60.

22 See AT III 286, 470, 491–2; this last passage is translated in CSMK 205–6.

23 See AT IV 72–3. The book was still in the process of being printed in May 1644; see AT IV 112–13, 122–3.

24 Some mention must be made of the notions of substance, duration, order, and number, which are common to all existents and thus not understood through either thought or extension; see *Principles* Part I, art. 48. These notions appear in the *Rules* as the "common" simple natures [AT X 419: CSM I 44–5], and in the celebrated letter to Elisabeth of 21 May 1643 as one of the groups of "primitive notions" in terms of which everything is comprehended [AT III 665: CMSK 218]. Though they pertain to mental and material substances, these notions would not seem to be comprehended through the principal attribute, thought or extension.

25 Descartes seems to take a somewhat different point of view in his conversation with Burman; see AT V 156, translated in Cottingham, *Descartes' Conversation with Burman*, p. 17.

26 See *Principles* Part I, art. 63.

27 It is interesting to note here that the Latin *modus* means "way"; the word used in the French translation of the *Principles* is *façon*, also "way."

28 See, for example, Aristotle, *Categories*, I.2; St. Thomas, *On Being and Essence*, ch. 2, sect. 2, and Goclenius, *Lexicon philosophicum*, pp. 26ff and 1097–8.

29 "Risibility" is, strictly speaking, what was called a property; while not in the essence of a human being, it belongs to all and only humans. See Aristotle, *Topics* I.5 102a 17ff. The actual act of laughing is what was called a proper accident, something that can only be in a human being, but isn't in every human always. See Goclenius, *Lexicon philosophicum*, p. 28.

30 See the references given above in note 15 for the earliest suggestions of Descartes' doctrine on the nature of body.

31 See AT VII 79–80: CSM II 55.

32 It is important to note, though, that in responding to Hobbes, Descartes denies that the wax example is intended to establish anything about the nature of body. See AT VII 175: CSM II 124.

33 The French version of this article adds a positive statement about their nature: "and that its nature consists in this alone, that it is a substance which has extension." Note also the very similar argument in *Principles* Part II, art. 11, where Descartes is arguing that "the extension constituting the nature of a body is exactly the same as that constituting the nature of a space."

34 See also the discussion in the *First Replies*: AT VII 120–1: CSM II 85–6.

35 "Act" [*actus*] is not to be understood as an action, but in the scholastic sense, as an actuality, something real.

36 In the 1643 letters to Elisabeth on mind–body union and interaction, Descartes adds a third class, those that depend on the union of mind and body, see AT III 665–6: CSMK 218.

37 Again, "act" is to be understood as a technical term. The French translation of this passage has an interesting variant; instead of saying that all corporeal acts "agree in the common concept of extension," the French

says that "they agree with one another insofar as they presuppose extension" (AT IXA 137). See also AT VII 121, 423–4: CSM II 86, 285–6.

38 Aristotle's main attack on the vacuum can be found in the *Physics* IV.6–9.

39 See Grant (ed.), *A Source Book in Medieval Science*, p. 48. The relevant section of the condemnation is § 49. The objection assumes a finite world, as both Aristotle and his medieval followers generally did.

40 See Grant, *Much Ado about Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution*, for an account of the history of theories of space and vacuum.

41 So far as I can see, there is no clear reason to believe that Descartes seriously confronted the problem of the vacuum before the latest stages in the composition of the *Rules*. There, in Rule XIV, he suggests that at least in imagination, there is no distinction between body and extended space. However, there is also a suggestion there that while body and space are indistinguishable in imagination, they may be distinguishable by reason. See AT X 442–6: CSM I 59–62. It seems clear that Descartes denies the vacuum by the time he was working on *The World*. But it is interesting that in ch. 4, where the topic is discussed, there are no real arguments against the vacuum; Descartes gives only weaker considerations designed to show that we cannot infer that there is empty space from the fact that we don't see a body in a given place. See AT XI 16–23: CSM I 85–8.

42 The French version is slightly different. See also AT V 194: CSMK 355 and AT V 272–3: CSMK 363–3. It is by no means easy to picture exactly what the vessel would look like the moment after God did the deed. Jammer suggests that what Descartes imagines is that the vessel would simply implode due to the pressure of the external atmosphere, though he (wrongly) claims that Descartes had no conception of atmospheric pressure. See Jammer, *Concepts of Space: The History of Theories of Space in Physics*, pp. 43–4. But surely this is not what Descartes imagined.

43 Diogenes Laertius, *Lives of Eminent Philosophers* X 41–2; see also idem, X 54 and Lucretius, *De rerum natura*, I 483ff.

44 For evidence of Descartes' possible earlier atomism, see the references cited above in note 12. Evidence on Descartes' views in the 1620s is inconclusive. The earliest text I know of in which Descartes comes out conclusively against atoms is a letter to Mersenne, 15 April 1630, AT I 139–40: CSMK 21–2.

45 See *Principles* Part II, arts. 33–4. Descartes does not claim that all bodies are in this state, of course. He recognizes three distinct elements, which are distinguished from one another by the size and shape of the particles that make them up. See *The World*, ch. 8, and *Principles* Part III, art. 52.

46 For other discussions of atomism, see also AT III 191–2; AT III 213–14: CSMK 154–5; AT III 477: CMSK 202; AT V 273: CSMK 363.

47 For the ancient atomists, the gods are themselves made up of atoms and do not have the power to split them. See, for example, Rist, *Epicurus: An Introduction*, ch. 8.

48 In his *Syntagma philosophicum*, Gassendi wrote: "There is no thing that God cannot destroy, no thing he cannot produce." See *Opera Omnia*, vol. I, p. 308 A. For general accounts of Gassendi's atomism see Jones, *Pierre Gasssendi, 1592–1655: An Intellectual Biography*; and Joy, *Gassendi the Atomist: Advocate of History in an Age of Science*, chap. 5.

49 See also *Principles*, pt. II, art. 23.

50 In advising his then-disciple Henricus Regius on how to deal with the attacks of the orthodox theologian, Gisbertus Voëtius, Descartes advises him to follow his example in the *Discourse* and *Essays*, and simply not mention that his natural philosophy does away with the scholastic forms. See AT III 491–2: CSMK 205–6. In the *Meteorology*, Descartes deftly skirts the question. See AT VI 239, translated in Olscamp, *Discourse on Method, Optics, Geometry and Meteorology*, p. 268. It is also notable that in the *Principles*, Descartes never discusses the issue of substantial forms, despite the fact that that work was originally intended as a direct answer to the scholastic textbook of Eustachius. On this, see Descartes' remarks to Father Charlet, assistant to the General of the Jesuits, to whom he sent a copy of the Latin *Principles* when they appeared in 1644; AT IV 141.

51 See AT II 364: CSMK 120; AT II 367; AT III 212; AT III 503–4, 505–6; AT III 648–49: CSMK 216. See also the French versions of *Principles* Part IV arts. 201, 203.

52 See also AT I 430, AT III 504, 506, and the introduction to the French version of the *Principles*: AT IXB 18–19: CSM I 189. This resembles Bacon's critique of the Aristotelian philosophy as all talk and no works; see, for example, the Preface to the *Great Instauration*, in Bacon, *The New Organon and Related Writings*, pp. 7–8. However, unlike Bacon, Descartes is not thinking of technological success, but of explanatory success.

53 This is a theme Descartes takes up at some length in the Sixth Replies. See AT VII 443–4: CSM II 298–9.

54 See Etienne Gilson's still classic essay, "De la critique des formes substantielles au doute méthodique," in his *Etudes sur le rôle de la pensée médiévale dans la formation du système cartésien*, pp. 141–90.

55 The main published discussion of animal souls is in Part V of the *Discourse*: AT VI 56–9: CSM I 139–41. The issue also comes up in the

Fourth Replies and in the Sixth Replies, as well as in the correspondence. See AT VII 230–1: CSM II 161–2; AT VII 426: CSM II 287–8; AT II 39–41: CSMK 99f; AT III 121; AT IV 575–6: CSMK 303–4; AT V 277–8: CSMK 365–6. For a general account of the question in Descartes and later thinkers, see Rosenfield, *From Beast-Machine to Man-Machine: Animal Soul in French Letters from Descartes to La Mettrie*.

56 See AT V 276–7: CSMK 365.

57 See AT XI 39: CSM I 93–4; AT II 597: CSMK 139.

58 This account of motion as change of place is also suggested in the *Rules*, where in Rule 12 Descartes points out that the ambient surface of a body can "be moved (*moveri*) with me in such a way that although the same [surface] surrounds me, yet I am no longer in the same place" (AT X 426: CSM I 49).

59 Descartes' contemporary, Henry More, was the first to claim that Descartes fashioned his definition of motion in the *Principles* specifically to allow himself to assert that the Earth could be regarded at rest, as he does in *Principles* Part III, arts. 28–9. See the "Preface General" to his *Collection of Several Philosophical Writings*, p. xi. For later discussions of this claim, see, for example, Koyré *Galileo Studies*, pp. 261, 265; Blackwell, "Descartes' Laws of Motion," pp. 220–34, esp. p. 277; Aiton, *The Vortex Theory of Planetary Motions*, pp. 33, 41–2; Dugas, *Mechanics in the Seventeenth Century*, pp. 172–3; and Westfall, *Force in Newton's Physics*, pp. 57–8. It is interesting that while many claim that Descartes fashioned the account of motion in the *Principles* specifically to deal with the problem of copernicanism, and thus that Descartes did not really believe that it is correct, hardly any two commentators agree on how precisely the definition is supposed to help. In the end, I find the claim highly implausible; see the discussion in ch. 6 of Garber, *Descartes' Metaphysical Physics*.

60 Interestingly enough, only a few years earlier Descartes himself had defined motion as an action, "the action through which the parts of . . . matter change place"; see Descartes to Morin, 12 September 1638: AT II 364.

61 See *Principles* Part II, art. 26.

62 See ibid. This also comes up in Descartes' letters to More: AT V 345–6, 348.

63 See also AT V 403–4: CSMK 382.

64 See also *Principles* Part II, art. 13, and Part III, art. 28.

65 See, for example in *The World*, ch. 6: AT XI 40: CSM I 94. Also see *Principles* Part II, arts. 27, 37, 44.

66 See, for example, Prendergast, "Descartes and the Relativity of Motion," pp. 64–72; Koyré, *Newtonian Studies*, pp. 81–2; Dugas, *Mechanics in the Seventeenth Century*, pp. 172–3; Aiton, *The Vortex Theory of Planetary Motions*, p. 33; and Westfall, *Force in Newton's Physics*, pp. 57–8.

67 See *Principles* Part II, art. 30.

68 For a different way of drawing the distinction between motion and rest in Descartes, see Martial Gueroult, "The metaphysics and physics of force in Descartes," in Gaukroger (ed.), pp. 196–229.

69 See also AT XI 11: CSM I 85.

70 The text given is translated from the Latin version. In the French version Descartes writes that things (bodies, presumably) change "through collision with others." Note that the formulation in the Latin version would seem to apply to mind as well as to body. Descartes, though, never makes use of this implication; indeed, it seems inconsistent with a view of the mind as active. For Descartes' follower, Henricus Regius, though, it is the ground of his account of the unity of mind and body. In the broadsheet he published declaring his views on mind, Regius writes: "the bond which keeps the soul conjoined with the body is the law of the immutability of nature, according to which everything remains in its present state so long as it is not disturbed by anything else" (AT VIIIB 344: CSM I 295). The same view can be found in Regius' *Fundamenta physices*, p. 250. Descartes rejects this application of his principle; see AT VIIIB 357: CSM I 303.

71 See *Principles* Part II, arts. 46–52. The seven rules are summarized in the appendix to this chapter.

72 This point is especially stressed in Costabel, "Essai critique sur quelques concepts de la mécanique cartésienne," esp. pp. 250–1.

73 See *Principles* Part II, arts. 6ff.

74 For an excellent account of Descartes' notion of determination and his treatment of directionality, see Gabbey, "Force and inertia in the seventeenth century: Descartes and Newton," in Gaukroger (ed.), pp. 230–320, esp. pp. 248–60.

75 This feature has led to a "Cartesian" theory of mind–body interaction and the claim that mind acts on body by changing the direction of the motion of a body without changing its speed, in that way allowing for mind–body interaction without violating the conservation principle. For a discussion of this, as well as a discussion of the general scope of the laws of nature and the question as to whether they govern animate bodies or not, see Garber, "Mind, body, and the laws of nature in Descartes and Leibniz," pp. 105–33.

76 Leibniz' basic argument can be found in his *Discourse on Metaphysics*, art. 17, among many other places. For an account of the argument and Leibniz' debates with late seventeenth-century Cartesians, see Iltis, "Leibniz and the *vis viva* controversy," pp. 21–35.

77 For discussions of the impetus theory, a popular way of explaining the continued motion of bodies among medieval natural philosophers, see, for example, Edward Grant, *Physical Science in the Middle Ages*, pp. 48ff, and Maier, *On the Threshold of Exact Science*, chs. 4 and 5.

78 See also AT XI 40: CSM I 94.

79 For a discussion of scholastic conceptions of the nature of motion, see Maier, *On the Threshold of Exact Science*, ch. 1.

80 In 1613 Beeckman wrote in his journal the principle that "a thing once moved never comes to rest unless impeded." See de Waard, *Journal tenu par Isaac Beeckman de 1604 à 1634*, vol. I, p. 24, and AT X 60. Descartes almost certainly learned this from Beeckman; see the use he makes of it in the solution to the problem of free-fall he sketched out for Beeckman: AT X 78. For Galileo's version in 1632, see, for example, Galileo, *Dialogue Concerning the Two Chief World Systems*, pp. 20–1, 28, 147ff. Gassendi's version can be found in his *De motu impressu a motore translato* (1640), translated in Brush, *The Selected Works of Pierre Gassendi*, pp. 141, 143. Newton's principle of inertia is Law I of the "Axioms or Laws of Motion" from Book I of his *Mathematical Principles of Natural Philosophy* (1687).

81 See especially the insightful comparison between Descartes and Newton by Gabbey, in Gaukroger (ed.), pp. 287–97.

82 See AT XI 85; *Principles* Part III, art. 57.

83 See AT XI 45–6, 85; *Principles* Part II, art. 39; idem, Part III, art. 57.

84 See also *Principles* Part III, art. 55f and AT XI 44, 84f.

85 See the references cited below in note 99.

86 For a clear exposition of the basic ideas behind Descartes' impact contest model of collision, see Gabbey, in Gaukroger (ed.), pp. 245ff.

87 Strange as this consequence is, we must recognize that Descartes does not mean to say that this is the way bodies behave in our world. As he notes, the rules explicity omit any effects that might arise from the fact that the bodies in question are surrounded with fluid. This fluid can change the outcome drastically and allow a smaller body to set a larger resting body into motion. See *Principles* Part II, art. 53, particularly the passages added in the French version, as well as the additions to the French version of *Principles* Part II, art. 50. For general discussions of the force of rest, see, for example, Gueroult, in Gaukroger (ed.), pp. 197ff, and Gabbey, in Gaukroger (ed.), pp. 267ff.

88 Also important is a letter Descartes wrote to Claude Clerselier, 17 February 1645: AT IV 183–7. In response to Clerselier's evident puzzlement over the rules of impact in the Latin edition of the *Principles*, particularly those that involve one body at rest, Descartes introduces new ways of thinking about the problem that seem inconsistent with the simple impact contest model in the Latin *Principles*. The development of Descartes' thought on impact in the mid-1640s is treated in some detail in ch. 8 of Garber, *Descartes' Metaphysical Physics*.

89 See especially Leibniz's careful examination of Descartes' rules of impact in his "Critical Thoughts on the General Part of the Descartes' *Principles*," translated by Loemker, *Philosophical Papers and Letters*, pp. 383–412, esp. 398–403.

90 Descartes does mention it in his letter to Clerselier, though; see AT IV 186–7.

91 See *Principles* Part II, art. 37.

92 The claim that the impact-contest forces derive from law 1, though ingenious, is not unproblematic. Leibniz, who wants to deny the Cartesian ontology of geometrical bodies and explicitly add force as something over and above extension, makes the following remark on this claim to the Cartesian De Volder:

> You deduce inertia from the force any given thing has for remaining in its state, something that doesn't differ from its very nature. So you judge that the simple concept of extension suffices even for this phenomenon. . . . But even if there is a force in matter for preserving its state, that force certainly cannot in any way be derived from extension alone. I admit that each and every thing remains in its state until there is a reason for change; this is a principle of metaphysical necessity. But it is one thing to retain a state until something changes it, which even something intrinsically indifferent to both states does, and quite another thing, much more significant, for a thing not to be indifferent, but to have a force and, as it were, an inclination to retain its state, and so resist changing (*Philosophical Papers*, ed. Loemker, p. 516).

93 See, for example, Descartes' formulation of this in the Third Meditation: AT VII 49: CSM II 33. When this is questioned by Gassendi, Descartes responds by saying that "you are disputing something which all metaphysicians affirm as a manifest truth" (AT VII 369: CSM II 254). He continues by paraphrasing the account of the doctrine found in St. Thomas, *Summa Theologiae* I, Q.104 a 1.

94 The issue of the ontological status of force in Descartes is a tangled one, though. For other views, see, for example, Guéroult, in Gaukroger (ed.), Gabbey, in Gaukroger (ed.), pp. 234–9; and Hatfield, "Force (God) in Descartes' physics," pp. 113–140.

95 See also AT V 381; Descartes evidently missed the question the first time around, and More had to repeat it.

96 AT V 347: CSMK 375; *Principles* Part II, art. 40.

97 See, for example, Hoenen, "Descartes's mechanicism," in Doney (ed.), *Descartes*, pp. 353–68, esp. p. 359.

98 Rather than identifying body as the active cause of a sensation, in the Latin *Principles* Descartes says, more vaguely, that "we seem to ourselves clearly to see that its idea comes from things placed outside of us" (*Principles* Part II, art. 1, Latin version). The French is vaguer still: "it seems to us that the idea we have of it forms itself in us on the occasion of bodies from without" (*Principles* Part II, art. 1, French version). It is, by the way, important not to conclude that Descartes was an occasionalist on the basis of this and other similar uses of the term "occasion," which did not seem to become a technical term until later in the seventeenth century.

99 There is relatively little in the way of secondary literature on Descartes' physics, when one gets beyond the foundations. Scott, *The Scientific Work of René Descartes*, offers a summary of Descartes' main scientific writings, but nothing more than that. For a general discussion of Descartes' science, with particular attention to its later influence, see Mouy, *Le Développement de la physique Cartésienne: 1646–1712*. For more specialized studies, see the essays collected in Milhaud, *Descartes savant*; and Costabel, *Démarches originales de Descartes savant*. For more recent work, see the essays by Crombie, Armogathe, Pessel, Rodis-Lewis, and Costabel in Grimaldi and Marion (eds.), *Le Discours et sa méthode* and the essays by Costabel, Wickes and Crombie, Zarka, and Rodis-Lewis in Méchoulan (ed.), *Problématique et réception du Discours de la méthode et des essais*. On questions relating to light and optics, see especially Sabra, *Theories of Light from Descartes to Newton*, and Shapiro, "Light, pressure, and rectilinear propagation: Descartes' celestial optics and Newton's hydrostatics." On Descartes' vortex theory of planetary motion and its later fate, see Aiton, *The Vortex Theory of Planetary Motions*.

GARY HATFIELD

11 Descartes' physiology and its relation to his psychology

Descartes understood the subject matter of physics to encompass the whole of nature, including living things. It therefore comprised not only nonvital phenomena, including those we would now denominate as physical, chemical, mineralogical, magnetic, and atmospheric; it also extended to the world of plants and animals, including the human animal (with the exception of those aspects of human psychology that Descartes assigned solely to thinking substance). In the 1630s and 1640s Descartes formulated extensive accounts of the principal manifestations of animal life, including reproduction, growth, nutrition, the circulation of the blood, and especially sense-induced motion. In connection with the latter he discussed at length the bodily conditions for psychological phenomena, including sense perception, imagination, memory, and the passions. He also examined the mental aspects of these phenomena, sometimes by way of complementing his physiological discussions and sometimes as part of his investigation into the grounds of human knowledge.

Philosophical readers may be curious about the relation between these scientific pursuits (Descartes would have called them natural philosophical or physical) and Descartes' philosophy, where the latter is conceived as his contribution to metaphysics and epistemology. Descartes' physiological and psychological writings bear directly on central topics in his philosophy, notably on the relation between mind and body and on the theory of the senses. With respect to the first, they exemplify Descartes' attempt to distinguish mind (or soul) from body and they raise the question of mind–body interaction. With respect to the second, they explain the functioning of the senses that conditions their use in acquiring knowledge, and they exemplify the metaphysics of sense percep-