Introduction

Natural philosophy lay at the core of Descartes' philosophical enterprise, and he instituted the most comprehensive reform of philosophy that has ever been attempted. His achievement was wide-ranging: he completely reformulated metaphysics by exploring its epistemological credentials in a wholly novel and indeed unprecedented fashion; he led the way in seventeenth-century cosmology up until Newton; he was one of the founders of modern geometrical optics; his contribution to mathematics was second to none in the seventeenth century; and he not only discovered reflex action, but developed a mechanistic approach to physiology which set the parameters for much thinking about physiology in the eighteenth and nineteenth centuries. The variety of Descartes' interests is not always immediately evident, however. This is partly because – unlike philosophers of similar standing such as Plato, Aristotle, and Kant – Descartes is usually approached through a single concern, namely the foundationalist metaphysics that is set out in similar ways in *Le Discours de la Méthode*, the *Meditationes*, and the *Principia Philosophiæ*. It is also partly because we can discern a plausible systematic connection between many of the parts of the Platonic or Aristotelian or Kantian corpus, which we cannot do in the case of Descartes. These two points are connected: Descartes' foundationalist metaphysics is so notoriously problematic that it is difficult to get beyond it to what it is supposed to provide the foundation for, and, in any case, if the foundations are not viable, there would seem to be little to be gained in asking what plausible systematic connection there could be between them and what is built upon them. The problem here derives in large part from a widespread but manifestly mistaken conception of the relation between the foundations and the rest of the system in Descartes. Descartes' system of natural philosophy is not generated by inference from first principles, but has been established quite independently of these first principles. In structuring his system around first principles, what Descartes hopes to achieve is a particular

kind of legitimation of the whole project. Why he seeks to legitimate his philosophy in the first place, and why he goes about legitimating it in this way, are matters that will concern us in what follows, where we shall be reconstructing Descartes' mature system of natural philosophy, and investigating the systematic connections between its various parts.

At the beginning of 1641, Descartes began work on what was initially envisaged as a six-part treatise. The first four parts were published as *Principia Philosophiæ* in 1644. These dealt with the 'principles of human knowledge', the 'principles of material objects', the 'visible universe', and 'the Earth'. In article 188 of Part IV of the *Principia*, Descartes tells us that he had intended to write 'two other parts: a fifth, concerning living things, or animals and plants, and a sixth, concerning man', but that he had not had the leisure to finalise these parts. He proceeds to describe what he had intended to cover, however, and it quickly becomes clear that the material for the last two parts is available, in one form or another, elsewhere in his writings. We shall be concerned not just with the work that was published under the title of *Principia Philosophiæ*, but also with the two projected final parts of the *Principia*, which I shall be reconstructing from these other materials.

Drawing on related material to reconstruct Descartes' project is not as problematic as it might first seem. The content of the *Principia* is not *sui generis*, nor even a novel departure from his earlier writings. Descartes reworked earlier material, including earlier published material as well as material intended for publication, throughout his writings. The published parts of the *Principia* are an exemplary instance of this. Part I reworks material already presented in the *Meditationes*, which itself revises material already presented in *La Discours*. Parts II and III rework material from *Le Monde*, and Part IV reworks material published in *Les Meteores*, which itself relies upon parts of *Le Monde*.

The content of the projected Part V is not difficult to reconstruct. *Le Monde* had covered the same material as Parts II to IV of the *Principia*, and had been succeeded by *L'Homme*, which dealt with animal physiology. It is true that Descartes mentions 'animals and plants' as being the subject of Part V, and *L'Homme* does not deal with plants, but we shall see that he holds there to be a continuity between plant and animal physiology, something entirely in keeping with his unified mechanistic reduction of organic processes. *L'Homme* was put to one side in 1633, but Descartes kept up work in anatomy and physiology through the 1630s and early 1640s, and he in part rewrote and updated *L'Homme* in the 1640s in *La Description du Corps Humain*, which remained unfinished. This

material is summarised very briefly at the beginning of *Les Passions de l'Ame*, published in 1649. *Les Passions* takes us from the physiology and psycho-physiology of the projected Part V into the intricacies of the mind/body as they relate to affective states. It is a treatise on human psychology, and, in the last instance, on the nature of morality. It is, in short, the basis for Part VI of the *Principia*.

As regards the sources of the *Principia*, as well as Descartes' earlier projects, there was a late Scholastic textbook tradition which offered a comprehensive treatment of philosophy, and the *Principia* was modelled on these textbooks. Descartes' first proposal had in fact been to write a double textbook, his own followed by a reprinting of the *Summa philosophiæ* (1609) of Eustachius a Sancto Paulo, with his annotations to this. He subsequently abandoned this project, but stuck with the idea of presenting his work in the form of a textbook. The textbook tradition provided a format for a comprehensive account of natural philosophy, identifying the topics to be included and their ordering, and, although Descartes reshapes this arrangement to his own purposes, his account is in many respects in line with the textbook tradition and is couched in the language of late Scholastic philosophy. However, late Scholastic metaphysics, and the natural philosophy it grounds, is theologically driven, whereas Descartes' foundationalist metaphysics is driven by epistemology. This is particularly important because there is no evidence of any interest in a foundationalist metaphysics before the abandonment of *Le Monde*, and its introduction, as we shall see, was a legitimatory device that was directly provoked by the view of the Inquisition that condemned Galileo in 1633 that claims for the physical reality of a cosmology could not be settled on purely natural–philosophical grounds. Descartes' project was to show that his natural philosophy was not just one amongst many, but the only one that could be reconciled with a particular set of metaphysical considerations whose distinguishing feature was that they could not be faulted or even doubted.

In other words, there was nothing internal to Descartes' project in natural philosophy that required metaphysical foundations, and there was nothing crucial to his natural philosophy that could only be generated from such metaphysical foundations. This does not mean, however, that the foundationalist metaphysics he provides is simply an added extra that can be stripped from the natural philosophy he sets out. On the contrary, Descartes makes it clear that it is in virtue of such a metaphysics that his natural philosophy is not simply one amongst many, but the one uniquely suited to revealing the ultimate constituents and structure of

the cosmos. That his natural philosophy is a metaphysically grounded one is a key part of Descartes' project, and this is something important not only in the physical theory of Parts II, III, and IV, but also in the physiology and psycho-physiology of Parts V and VI. The constraints on this metaphysics are provided by a number of sources, not least the Scholastic vocabulary he takes up, but above all by the dictates of his natural philosophy. Indeed, the fact that natural philosophy ultimately provides the tasks for his metaphysics, rather than these tasks being generated directly by a definition of the subject matter of natural philosophy provided by metaphysics, is one of the features of Descartes' project that marks it out from the late Scholastic approaches against which he is pitting his own system.

The reconstructed *Principia* provides us with a comprehensive account of Descartes' mature philosophy, beginning with metaphysical foundations of natural philosophy, and ending with the implications of his natural philosophy for morality. In the course of this, Descartes completely reshapes the relations between metaphysics and natural philosophy, and develops the first mechanist physical cosmology, the first non-mythological theory of the formation of the Earth, the first mechanist physiology and embryology, the first mechanist account of animal sentience, an account of the nature of mental functioning that goes beyond anything devised to that time and which has largely shaped discussions of the mind since, and an account of human passions that demonstrates the need for a unified conception of the person. This is the 'system of natural philosophy' that we shall be exploring in what follows.

CHAPTER 1

Before the Principia

In each of the decades of his maturity, Descartes embarked upon an unfinished project: the *Regulae* in the 1620s, *Le Monde/L'Homme* in the 1630s, and the *Principia* in the 1640s. The first two of these projects inaugurate major changes of direction in Descartes' thinking, while the third attempts to consolidate a major development begun in *La Discours de la Méthode* and the *Meditationes*. There are some themes that persist, however, and this is particularly true of *Le Monde/L'Homme*, which provides much of the material for the final project. Indeed, in thinking through this final project, Descartes talks of teaching *Le Monde* 'to speak Latin' before bringing it into the world, and 'naming it *Summa Philosophiæ* to make it more welcome to the Scholastics, who are now persecuting it and trying to smother it before its birth'.[1]

Between the abandonment of *Le Monde* and the publication of the *Principia*, Descartes formulated some of his results in method, optics, meteorology, and geometry in the form of four essays, published in 1637, and then he turned away from explicit natural philosophy for a while. Developing a theme that had already been evident in the first of these essays, *Le Discours*, he set out a sceptically driven epistemology as a way of indicating the tasks of a foundational metaphysics in the *Meditationes*. Then, 'when I thought that these earlier works had sufficiently prepared the minds of my readers to accept the *Principia Philosophiæ*, I published these too'.[2] The *Principia* is the work in which the foundational tasks are carried out, and it begins its account with a number of fundamental claims about the nature of knowledge, claims that had been worked out in detail in *Le Discours* and in the *Meditationes*. In these texts, Descartes had provided a metaphysical foundation for knowledge, something wholly absent from *Le Monde*, and indeed from anything he wrote before the mid 1630s. The remaining three books, then, present a revised version of

[1] Descartes to Huygens, 31 January 1642; AT III. 523. [2] AT IXB. 16.

Le Monde, with some important additions (such as the rules of collision and the account of the formation of planets) and some important revisions (such as the doctrine of the reciprocity of motion). The *Principia* appears, in sum, as a revised version of the project of *Le Monde/L'Homme*, prefaced by a foundationalist metaphysics which reshapes some of the natural–philosophical doctrines of the earlier writings, and – taking *Les Passions de l'Ame* as providing a version of the final part of the exercise – culminating in an account of human psychology and the attainment of a moral life.

The *Principia*, in its projected complete form, offers us the mature Cartesian system, and, in order to come to terms with it, it is important that we understand what this system developed from, why it developed in the way it did, and just why Descartes chose to set out his system in the form of the *Principia*. To this end, my aim in this chapter is to explore the first and second of these questions by looking at Descartes' own earlier projects, particularly as they bear upon the *Principia* and its projected two final parts, and then, in the next chapter, to explore the third question by looking at possible models for the *Principia*.

'PHYSICO-MATHEMATICS'

'Physico-mathematicians are very rare', wrote Isaac Beeckman in a diary entry for December 1618, shortly after meeting Descartes for the first time, and he notes that Descartes 'says he has never met anyone other than me who pursues his studies in the way I do, combining physics and mathematics in an exact way. And for my part, I have never spoken with anyone apart from him who studies in this way.'[3] It was Beeckman who introduced Descartes to a quantitative micro-corpuscularian natural philosophy, one that he was to reshape and make into his own very distinctive system of natural philosophy.[4]

Descartes' earliest writings, which derive from late 1618/early 1619, deal with questions in practical mathematical disciplines. He composed a short treatise on the mathematical basis of consonance in music, exchanged letters with Beeckman on the problem of free fall, and worked

[3] *Journal tenu par Isaac Beeckman de 1604 à 1634*, ed. Cornelius de Waard, 4 vols. (The Hague, 1939–53), I. 244.

[4] On the details of Descartes' relationship with Beeckman, see Klaas van Berkel, 'Descartes' Debt to Beeckman: Inspiration, Cooperation, Conflict', in Stephen Gaukroger, John Schuster, and John Sutton, eds., *Descartes' Natural Philosophy* (London, 2000), 46–59. On how Descartes reshaped his early work with Beeckman see Stephen Gaukroger and John Schuster, 'The Hydrostatic Paradox and the Origins of Cartesian Dynamics', *Studies in History and Philosophy of Science*, forthcoming.

with him on a number of problems in hydrostatics.[5] The second, and particularly the third, of these exercises are of interest. In the correspondence on free fall,[6] Beeckman poses Descartes a mathematical question about the relation between spaces traversed and times elapsed in free fall, but Descartes seems keen to steer the question in the direction of dynamics, seeking the nature of the force responsible for the continued increase in motion. The move is not successful, and in fact it leads Descartes to misconstrue the original problem, but it is indicative of what will be an important and productive feature of his thinking about mechanical problems, and later about physical problems more generally.

The hydrostatics manuscripts[7] are of even greater interest in this respect. Here Descartes turns his attention to a paradoxical result that Simon Stevin had proved in hydrostatics, namely that the pressure exerted by a fluid on the base of its container is independent of the weight of the fluid and, depending on the shape of the vessel, can be many times greater than its weight. Here, Descartes takes a question which has been solved in rigorous mathematical terms and looks for the underlying physical causes of the phenomenon. He construes fluids as being made up from microscopic corpuscles whose physical behaviour causes the phenomenon in question, and he asks what kinds of behaviour in these corpuscles could produce the requisite effect. This is, in effect, an attempt to translate what Stevin had treated as a macroscopic geometrical question into a dynamically formulated micro-corpuscularian account of the behaviour of fluids. In the course of this, Descartes develops a number of rudimentary dynamical concepts, particularly his notion of *actio*, which he will use to think through questions in physical optics in the mid 1620s, and then questions in cosmology in 1629. This is of particular importance because his whole approach to cosmological problems, for example, is in terms of how fluids behave, and, as we shall see, it is fluids that carry celestial bodies around in their orbits.

THE *REGULAE*

Later in 1619, Descartes began work on the *Regulae*. His principal interest had shifted to mathematics by this time, and this interest was stimulated by reflection upon an instrument called a proportional compass, which had limbs that were attached by sliding braces so that, when the compass was opened up, the distances between the limbs were always in the same

[5] On these see my *Descartes, An Intellectual Biography* (Oxford, 1995), ch. 3.
[6] AT x. 58–61, 75–8, 219–22. [7] AT x. 67–74, 228.

proportion.[8] The proportional compass enabled one to perform geometrical operations, such as trisection of angles, and arithmetical ones, such as calculation of compound interest, and Descartes asked how it was possible for the same instrument to generate results in two such different disciplines as arithmetic, which dealt with discontinuous quantities (numbers), and geometry, which deals with continuous quantities (lines). Since the principle behind the proportional compass was continued proportions, he realised that there was a more fundamental discipline, which he initially identified with a theory of proportions, later with algebra. This more fundamental discipline had two features. First, it underlay arithmetic and geometry, in the sense that, along with various branches of practical mathematics such as astronomy and the theory of harmony, these were simply particular species of it, and for this reason he termed it *mathesis universalis*, 'universal mathematics'. Its second feature was that this universal mathematics was a problem-solving discipline: indeed, an exceptionally powerful problem-solving discipline whose resources went far beyond those of traditional geometry and arithmetic. Descartes was able to show this in a spectacular way in geometry, taking on problems, such as the Pappus *locus*-problem, which had baffled geometers since late antiquity, and he was able to show how his new problem-solving algebraic techniques could cut through these effortlessly. In investigating the problem-solving capacity of his universal mathematics, however, Descartes suspected that there might be an even more fundamental discipline of which universal mathematics itself was simply a species, a master problem-solving discipline which underlay every area of inquiry, physical and mathematical. This most fundamental discipline Descartes termed 'universal method', and it is such a method that the *Regulae* sought to set out and explore.

When Descartes began work on the *Regulae*, it was intended to be in three parts, each part to contain twelve 'Rules'. What was offered was a general treatise on method, covering the nature of simple propositions and how they can be known (first twelve Rules), how to deal with 'perfectly understood problems' (second set of Rules), and 'imperfectly understood problems' (projected third set). The composition proceeded in two stages, however, and the nature of the work shifted somewhat between stages.[9] In 1619–20, Descartes completed the first eleven Rules, and then apparently

[8] See my *Descartes, An Intellectual Biography*, ch. 4 for details.

[9] On dating see Jean-Paul Weber, *La Consitution du texte des Regulae* (Paris, 1964) and John Schuster, 'Descartes' *Mathesis Universalis*, 1619–28', in Stephen Gaukroger, ed., *Descartes, Philosophy, Mathematics and Physics* (New York, 1980), 41–96.

abandoned them. When he took up the *Regulae* again in 1626–8, he revised two of these (Rules 4 and 8) and added Rules 12 to 18, with titles only for Rules 19–21. The thrust of the work remains methodological, and mathematics is still taken very much as model – which is what we would expect, since the fact that the move to universal method comes through universal mathematics is what provides the former with its plausibility. But the complete Rules of the second Part, particularly Rules 12 to 14, focus on the question of how a mathematical understanding of the world is possible by investigating just what happens in quantitative perceptual cognition, that is, just what happens when we grasp the world in geometrical terms. The change in focus is interesting, but it is not thoroughgoing, and severe problems arise in reconciling universal method with universal mathematics, which has now become algebra.

Specifically, the problem that Descartes faced was that universal method was supposed to provide a general form of legitimation of knowledge, including mathematical knowledge, but algebra also provided its own specific kind of legitimation of mathematical knowledge, and the point at which the *Regulae* break off and are abandoned is exactly that at which it becomes clear that these two forms of legitimation come into conflict. The general form of legitimation provided by universal method is one in which problems are represented in the form of clear and distinct ideas, and Rule 14 spells out just what this means in the case of mathematics: it means representing the pure abstract entities that algebra deals with in terms of operations on line lengths, and in this way the truth or falsity of the proposition so represented is evident. To take a simple example, the truth of the proposition $2 + 3 = 5$ is not immediately evident in this form of representation, but it is evident if we represent the operation of addition as the joining together of two lines, as in Figure 1.1.

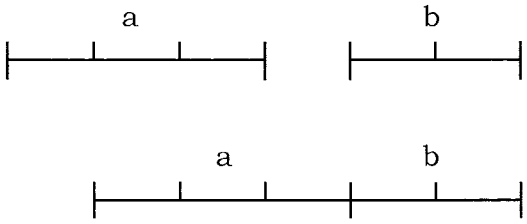

Figure 1.1

In this case we can see how the quantities combine to form their sum (and this is just as evident in the case of very large numbers the numerical value

of whose sum we cannot immediately compute). This is a very insightful and profound move on Descartes' part. The problem he is concerned with is that of identifying those forms of mathematical demonstration not merely in which we can grasp that the solution or conclusion follows from the premises, but in which we can track how the solution or conclusion is generated. The difficulty that arose was that the range of operations for which this kind of basic legitimatory procedure held did not extend to the more sophisticated kinds of operation with which Descartes' algebra was able to work. And it is just such operations that begin to be envisaged in Rules 19–21, namely the extraction of higher-order roots, where no manipulation of line lengths is going to generate the result.

It is at this point that the *Regulae* are abandoned, and this also marks the end of the attempt to model knowledge on mathematics, at least in anything other than a merely rhetorical sense. When mathematics is invoked from now on, it will be invoked as a paradigm of certainty, but, in contrast to the work of the 1620s, it will cease to be accompanied by an attempt to capture at any level of mathematical detail just what this certainty derives from or consists in. Indeed, Descartes' interest in methodological questions in his later writings comes to be overdetermined by metaphysical, epistemological, and natural–philosophical issues.

LE MONDE AND *L'HOMME*

At the end of 1629, Descartes began work on a new project, which he later described to Mersenne in these terms:

> Since I tried to explain the principles in a Treatise which certain considerations prevented me from publishing, I know of no better way of making them known than to set out here briefly what it contained. I had as my aim to include in it everything that I thought I knew before I wrote it about the nature of material things. But just as painters, not being able to represent all the different sides of a body equally well on a flat canvas, choose one of the main ones and set it facing the light, and shade the others so as to make them stand out only when viewed from the perspective of the chosen side; so too, fearing that I could not put everything I had in mind in my discourse, I undertook to expound fully only what I knew about light. Then, as the opportunity arose, I added something about the Sun and the fixed stars, because almost all of it comes from them; the heavens, because they transmit it; the planets, comets, and the Earth, because they reflect light; and especially bodies on the Earth, because they are coloured,