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RENÉ DESCARTES
The World

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RENÉ DESCARTES

The World
and Other Writings

TRANSLATED AND EDITED BY
STEPHEN GAUKROGER
University of Sydney

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In translating and annotating *The World*, I have found a number of works of great value. In October 1996 a new edition of the texts with detailed annotations by Annie Bitbol-Hespériès and Jean-Pierre Verdet was published as *René Descartes: Le Monde, L'Homme* (Paris). Although this appeared after I had drafted the notes to this edition, I still found it of great use, as I did the annotations by Michael Mahoney to his translation of the *Treatise on Light* which appeared as *René Descartes: Le Monde, ou Traité de la Lumière* (New York, 1979). Above all, I am indebted to the copious and invaluable annotations by Thomas Hall in his translation of the *Treatise on Man*, which appeared as *René Descartes: Treatise of Man* (Cambridge, Mass., 1972). The other major work included in full here, the *Description of the Human Body*, has, so far as I know, not appeared in English in its entirety before.

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Introduction

The origins of *The World*

The *Treatise on Light* and the *Treatise on Man* – which I shall refer to under the collective title *The World* – together constitute the most ambitious systematic project that Descartes ever undertook. Neither appeared in his lifetime. The first was published posthumously as *Le Monde* in 1664, the second two years earlier as *Renatus Descartes de Homine*. Both are parts of what is ostensibly a single work, and form the backbone of a single treatise. The text went through a number of redraftings, not just with respect to the detail of the arguments but also with respect to what should be included in the treatise, and the project included not only the *Treatise on Light* and the *Treatise on Man*, but also the material on the formation of colours in the *Meteors* and the material on geometrical optics in the *Dioptrics*, both subsequently published in 1637 along with the *Discourse* and the *Geometry*. I have included this material as appendices to the text of the *Treatise on Light*. There are also indications that Descartes had originally intended incorporating other material, including some work on music, for example, although this is not extant and may never have been developed in a systematic way.

The core doctrine at stake in *The World* is that of mechanism – above anything else, the doctrine that matter is completely inert – and Descartes' aim is to provide a mechanistic cosmology, resting on the basis of quantitative 'laws of nature', and a mechanistic physiology. Among the more fundamental things that he sets out to establish, four are of special significance and novelty. The first is that the stability of planetary orbits and the orbits of their moons can be accounted for on a mechanist basis if we envisage the planets being carried in a sea of fluid matter which takes the form of a vortex. The second is that the propagation of light from the Sun can be explained in terms of the centrifugal effects of its axial rotation. The third is that all vital functions can be accounted for mechanistically. And the fourth is that perceptual cognition can be accounted for, at least to a very large extent, in terms of a mechanistic psycho-physiology.

Descartes began *The World* in October 1629, and abandoned it, on hearing of the condemnation of Galileo,[1] at the end of 1633. From the account given in Part v of the *Discourse on Method*, it seems that the original project was designed to cover three topics: inanimate nature, animals and especially the human body, and the 'rational soul'. The descriptions of the first and second parts correspond closely to what we have in the *Treatise on Light* and the *Treatise on Man* respectively, but the third part of the project is not extant, and although in Part v of the *Discourse*, in describing *Treatise on Light*, Descartes says that after completing the *Treatise on Man* he 'described the rational soul', it may never have even been drafted at this time.

Descartes had earlier devoted some attention to at least some aspects of the three areas that he intended to pursue in *The World*, but with nothing like the breadth of vision.[2] Isaac Beeckman[3] had introduced Descartes to a micro-mechanical form of corpuscularian natural philosophy in late 1618/early 1619, and Descartes' early exercises in hydrostatics took the form of an attempt to explain macroscopic phenomena in micro-corpuscularian terms. This early work in statics provided him with his notions of 'action' and 'tendency to motion' (bodies hardly ever move in Descartes' mechanics: rather, they exhibit 'tendencies to motion', something encompassed by his general term 'action'), as well as providing him with a model of physical explanation in which one seeks to understand how physical processes are modified as one moves from one system of constraints to another, as opposed to the far more common seventeenth-century model of corpuscles moving in a void. Indeed, his early concern with explaining the behaviour of bodies in fluids is carried over in a

[1] Galileo Galilei (1564–1642) was the leading proponent of the heliocentric theory in the first part of the seventeenth century, his *Dialogue Concerning Two Chief World Systems* (1632) offering an elaborate defence of heliocentrism. It was quickly condemned by the Roman Inquisition, copies withdrawn, and Galileo, after recanting, was put under house arrest.

[2] For the details of Descartes' early intellectual development in the period before he began work on *Le Monde*, see chs. 1–6 of Stephen Gaukroger, *Descartes: An Intellectual Biography* (Oxford, 1995).

[3] Isaac Beeckman (1588–1637) was a Dutch engineer, physician, and educational administrator who pioneered the development of a purely mechanistic physical theory.

striking way into the *Treatise on Light*, where the motion of the planets results in large part from the motion of the fluid in which they are embedded. But Descartes' concern with physical questions at this time oscillated between extremely specific exercises, such as the explanation of free fall and Stevin's hydrostatic paradox in 1618–19, and very programmatic statements on universal method in the early 1620s. Although he had discovered the sine law of refraction some time in the mid- to late 1620s, and had investigated the physical basis for the law, before *The World* he seems to have had very little success in finding the right level at which to formulate a natural philosophy which had both real empirical content and offered a genuinely broad conceptual understanding of natural processes.

The subject of the *Treatise on Man* is animal physiology. Except for the question of perceptual cognition, there is no record of any general interest in anatomy and physiology before his move to the Netherlands at the end of 1628. Descartes had pursued perceptual cognition in an ingenious way in Rules 12–14 of the *Rules for the Direction of the Native Intelligence*, composed some time between 1626 and 1628. In these Rules he restricted his attention to the psycho-physiology of perceptual cognition, investigating the way in which sensed objects are represented by means of line lengths in the imagination. By this time Descartes had a firm understanding of geometrical optics, and a good basic understanding of faculty psychology, and his aim was to construe perceptual cognition along largely mechanist lines in terms that made no reference to the traditional 'vegetative' and 'sensitive' souls. By the time of his move to the Netherlands, however, we begin to find a more systematic interest in anatomy and physiology. He tells Mersenne[4] in a letter of 18 December 1629 (AT i. 102) that he has taken up the study of anatomy,[5] and during his first winter in Amsterdam he would visit the butcher daily to watch the slaughtering of cattle, and would take parts he intended to dissect back to his lodgings.[6] He seems to have kept up an interest in these topics throughout the period of composition of the first part of *The World*, and he continued work on the *Treatise on Man*, possibly making revisions to the manuscript, into the mid-1640s.

As regards the third part of the project, on the 'rational soul', although

[4] Marin Mersenne (1588–1648) was a pioneer in mechanist natural philosophy, musical theory and acoustics. His extensive correspondence forms the best guide to scientific thought in the years 1629–48. Descartes was one of his principal correspondents.

[5] Cf. Descartes to Mersenne, [20 February 1639], Adam and Tannery edition (abbreviated to AT hereafter) ii. 525.

[6] Descartes to Mersenne, [13 November 1639]; AT ii. 621.

we have nothing that Descartes may have written on this question from this time, we do know that, amongst other things, he was working on a treatise on metaphysics in 1629–30. He mentions that he had begun work on 'a little treatise' in a letter to Gibieuf[7] in July 1629, and a later letter to Mersenne indicates that this was a treatise on metaphysics in which he 'set out to prove the existence of God and of our souls when they are separate from the body, from which their immortality follows'.[8] These were the two traditional questions that Parisian philosophers of the 1620s had been concerned with, and the projected third part of *The World* may well have drawn on material in the abandoned treatise on metaphysics, although it should be noted that when Descartes later summarises his mechanistic physiology it will be in the *Passions of the Soul*, where it acts as a prelude to an account of the passions, rather than to a metaphysical discussion of the nature of mind.

As far as the provenance of *The World* is concerned, it had modest beginnings. In a letter of October 1629 Descartes wrote to Mersenne seeking fuller information on a particularly striking appearance of 'false' or 'multiple suns' – parhelia – observed by the astronomer Christoph Scheiner[9] at Frascati, just outside Rome, on 20 March. Descartes had become quite excited about the question, and, realising that the phenomenon bore a striking similarity to rainbows, dropped other projects, including the treatise on metaphysics.[10] He tells Mersenne that he has been working on meteorological questions generally, and that his interest has outgrown a concern merely to explain parhelia. He has resolved 'to write a small treatise on [meteorology] which will contain the explanation of the colours of the rainbow, which has given me more trouble than all the rest and, in general, all sublunary phenomena'. But this will be no ordinary treatise, 'for I have decided to exhibit it publicly as a sample of my Philosophy, and to hide behind the canvas to listen to what people will say about it' (AT i. 23). The topic is one of the best he could choose for this purpose, he tells Mersenne, and he promises to send him the manuscript for publication when it is complete, as he would prefer that it be published in Paris.

7 Guillaume Gibieuf (c.1591–1650) was a French theologian who wrote on a number of metaphysical issues including freedom of the will.
8 Descartes to Mersenne, 25 November 1630; AT i. 182.
9 Christoph Scheiner (1575–1650) was a Jesuit mathematician and astronomer.
10 In October Descartes tells Mersenne that he has had to interrupt what he has been working on, which is almost certainly a reference to the treatise on metaphysics. See Descartes to Mersenne, 8 October 1629; AT i. 23.

By November, the project has grown even further, and he writes to Mersenne on 13 November that:

> I should tell you that it will be more than a year before it is ready. For since I wrote to you a month ago, I have done nothing at all except sketch its argument, and instead of explaining a single phenomenon, I have decided to explain all natural phenomena, that is, the whole of physics. And the plan gives me more satisfaction than anything previously, for I think I have found a way of presenting my thoughts so that they satisfy everyone, and others will not be able to deny them. (AT i. 70)

The move from parhelia, first of all to meteorological phenomena, then to the whole of the physical world, is a huge one and it had taken shape in Descartes' mind over a period of no more than four months, between August and November 1629.

In Part 5 of the *Discourse*, Descartes sets out the details of the treatise he was working on in the period from mid-1629 to 1633. He writes:

> I tried to explain the principles in a Treatise which certain considerations prevented me from publishing, and 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, or transparent, or luminous; and finally about man, because he observes these bodies. (AT vi. 41–2)

From 1629 to 1630, the problem that Descartes faced was that of building up his general knowledge of physics and related areas, sorting out what he should and should not concentrate upon, and finding a guiding thread by which to organise the argument of his treatise. The first and second problems took up a great deal of his time. In his letter to Mersenne of

15 April 1630 he complains that his 'work is going very slowly, because I take much more pleasure in acquiring knowledge than in putting into writing the little that I know' and that he is 'now studying chemistry and anatomy simultaneously'. But the third problem evidently gave him no less trouble. Later in the same letter he tells Mersenne that 'all these problems in physics that I told you I have taken on are all so interlinked and depend so much on one another that it is not possible for me to give a solution to one of them without giving a solution to all, and I cannot do that more quickly or more succinctly than in the treatise I am writing'. And in a letter to Mersenne of 23 December of that year he tells him that he has 'countless different things to consider all at once' and that he is trying to find some 'basis on which to give a true account without doing violence to anyone's imagination or shocking received opinion' (AT i. 194).

As for the order of composition, we know that Descartes worked on the *Treatise on Light* between 1630 and 1632. There is some evidence that it was proceeding in fits and starts in 1630, and that work on it was taking its toll on Descartes. In a letter of 15 April, for example, he asks Mersenne not to confirm to anyone that he is writing his treatise on physics but rather to give them the impression that he is not, for 'I swear that if I had not already told people that I planned to do so, with the result that they would say that I had not been able to carry out my plan, I would never undertake the task.' On the assumption that he wrote the chapters in the order in which they appear in the extant draft, he was up to chapter 5 by the end of February 1630 and had completed the material for chapters 6 to 8 in the first three months of 1632, the remaining chapters being drafted between then and late 1632. From late 1632 he concentrated on the *Treatise on Man*, and he had already done a considerable amount of work in physiology by this stage. At the end of 1632 he tells Mersenne that he will

> speak more about man than I had intended to before, because I shall try to explain all of his principal functions. I have already written about those that pertain to life, such as the digestion of food, the beating of the pulse, the distribution of nutrients etc., and the five senses. Now I am dissecting the heads of different animals in order to explain what imagination, memory etc., consist of. I have seen the book *De motu cordis* [of Harvey[11]] of which you spoke

[11] William Harvey (1578–1657) was an English physician and physiologist who discovered the circulation of the blood. His account of circulation, and the pumping action of the heart, was set out in *De motu cordis* (1628).

> to me earlier, and find I differ only a little from his view, which I came across only after I had finished writing about this matter. (AT i. 263)

From this time until mid-1633 he appears to have devoted himself to physiology.

The *Treatise on Light*

The first five chapters of the *Treatise on Light* form a kind of introduction, suggesting that matter and motion are sufficient to explain natural phenomena, and proceeding to set out the theory that the material world consists exclusively of matter (in particular, does not have any empty regions), and that this matter can be considered as comprising three sizes of corpuscle. The defence of mechanism offered starts off in the first three chapters as a very general and intuitive one, appealing to common-sense examples, while the remaining chapters of the first part shift to a more contentious version of mechanism, as Descartes moves from a consideration of the nature of liquidity and hardness to a micro-corpuscular theory of elements and a rejection of an inter-corpuscular void. Chapters 6 to 14 then use this micro-corpuscular theory of matter, combined with a number of laws describing the motion of the corpuscles, to set out a mechanistic cosmology which includes both a celestial physics and an account of the nature and properties of light. The text ends abruptly with an unfinished chapter 15.[12]

In the first chapter Descartes shows that our perceptual images need not resemble what they represent. What he is attacking here is the prevalent Aristotelian view that the veridicality of our perceptual images of the world lies in their ability to resemble the objects perceived. Descartes provides an example to show that a sensation need not resemble the cause of that sensation. But his account raises two deeper issues. First, he introduces a positive account of visual cognition according to which the way in which perceptual images represent the object perceived is modelled not on pictorial representation (as it had been in the *Rules*, for example, where the perceptual image takes the form of lines 'etched' on a two-dimensional surface), but on verbal understanding, so that our attention is drawn to the phenomenon of what might be called visual understanding, something that

[12] The original, presumably complete, manuscript seems to have consisted in 18 chapters: see AT xi. iii–iv. We have no indication what the content of the missing chapters was.

involves an irreducible element of interpretation on our part. Secondly, the thrust of his negative argument against the resemblance theory goes beyond the claim that the world may be different from our perceptual image of it, and what Descartes is really trying to steer us towards is the idea that our perceptual image may not even be a guide to how the world is. In particular, he suggests that light may be 'different in objects from what it is in our eyes'.

In the second chapter, he starts out on the task of establishing this. Turning directly to the nature of light, he points out that there are only two sorts of bodies in which light is found, namely the stars, and flame or fire, the latter being the more familiar and hence the best starting-point. The aim is to show how a macroscopic phenomenon can be accounted for plausibly in micro-corpuscularian terms, and fire is a good example for Descartes' purposes. We can see that the fire moves the subtler parts of the wood and separates them from one another, transforming them into fire, air, and smoke, and leaving the grosser pieces as ashes. All we need to postulate in order to account for the burning process is the motion of parts of the wood resulting in the separation of the subtle parts from the gross parts.

In the course of this discussion, Descartes tells us that he is not concerned with the direction of motion, making a sharp distinction between speed and direction. Now since, when something moves, it always moves in a direction, motion would appear to have both speed and direction, these being two inseparable components of the same thing. But Descartes sees matters differently. For him, the power by which something moves and the power which determines its motion as being in one direction rather than another are different powers. In his *Dioptrics*, to which he refers us here, he gives the example of a tennis ball being reflected off a hard surface. The thrust of the argument is that, because the tennis ball and the surface are inelastic, if force and direction of motion were the same thing then the ball would first have to stop before it changed direction, and if it stopped a new cause would be needed for it to move again. But there is no such new cause available: therefore, its force is not affected in the impact, only the direction of its motion, which is changed. The basic distinction that he wants to draw is between the power by which something moves and its 'determination', the latter being something that depends on the force or speed of the body, and which directs that speed or force. The geometrical configuration of other bodies can alter this determination and Descartes goes on to tell us that the actual path of a moving body is determined by each part moving 'in the manner made least difficult for it' by surrounding bodies.

At the beginning of chapter 3, Descartes draws attention to the prevalence of change in nature, but he argues that the total amount of motion in the universe is conserved, although this motion may be redistributed among bodies. His account of the difference between hard and fluid bodies in chapter 3 forms a bridge between a very general statement of the mechanist position, most of which would have been common ground to mechanists, and a specific version of micro-corpuscularianism which was both more distinctive and more contentious. The general principle from which Descartes works is that, given that all bodies can be divided into very small parts, a force is required to separate these parts if they are stationary with respect to one another, for they will not move apart of their own accord. If the very small parts of which the body is constituted are all at rest with respect to one another then it will require significant force to separate them, but if they are moving with respect to one another then they will separate from one another at a rate which may even be greater than that which one could achieve by applying a force oneself. The former bodies are what we call solids, the latter what we call fluids, and in the extreme cases they form the ends of a spectrum on which all bodies can be ranked, with rigid solids at one terminus and extremely fluid bodies at the other. This ranking on a spectrum of fluidity provides the basis for Descartes' theory of matter, for it enables him to reduce the properties of matter to the rate at which its parts move with respect to one another. At the extreme fluid end of the spectrum comes, not air as one might expect, but fire, whose parts are the most obviously agitated, and whose degree of corpuscular agitation is such that it renders other bodies fluid.

The discussion of the nature of air in chapter 4 opens with the question of the existence of imperceptible bodies. Descartes tells us he is clearing away a prejudice which we have from childhood, that the only bodies that exist are those that can be sensed, and that air is so faintly sensible that it cannot be as material or solid as those we perceive more clearly. All bodies, whether fluid or solid, are made from the one kind of matter. Descartes argues that the degree of fluidity of a body cannot be proportional to the amount of vacuum that exists between its constituent parts, trying to establish that there must be more space between the parts of a solid than between those of a liquid, because the moving parts of a liquid 'can much more easily press and arrange themselves against one another' than can the parts of a solid. His main conclusion is that if there is a vacuum anywhere it cannot be in fluids but must be in solid bodies, and he is more concerned to make sure that we accept that there are no interstitial vacua in fluids than to show the absence of such vacua in solids. This is because his account of the basic structure of the universe effectively subsumes it under fluid mechanics, and hence his interest is really in fluids. This begins to become evident in the subsequent discussion, where the question of the non-existence of a void is discussed in terms of the motion of fluids, and it becomes part of a question in fluid mechanics. In particular, the question arises of how bodies can move at all if there is no empty space for them to move into, and the answer Descartes gives is that 'all the motions that occur in the world are in some way circular'. With circular motion, matter could move in a plenum by means of a large-scale displacement: a region of matter will then be able to move when contiguous matter in the direction of its motion, and contiguous matter in the opposite direction, also move in the direction of its motion, and when the same conditions hold for these contiguous pieces of matter, so that in the end a continuous loop or ring of matter is displaced.

The doctrine of elements immediately follows the account of circular translation. He invokes only three elements – fire, air, and earth. This is to be explained by the fact that Descartes is writing a treatise on *light*. At an intuitive level, three kinds of process are involved, namely, the production of light, the transmission of light, and its reflection and refraction. Descartes' model of light is one drawn from fluid mechanics: it is something that acts by means of mechanical pressure, and what needs to be explained is how this mechanical pressure is generated in the first place, how it is propagated, and why light so construed behaves in particular geometrically defined ways when it encounters opaque and transparent bodies. Light is generated by fiery bodies, transmitted through the air, and is refracted and reflected by terrestrious bodies. The traditional elements of fire, air, and earth have, then, a cosmological analogue. These three elements are for Descartes simply three different sizes of corpuscle: very fine, fine, and gross respectively. They are the kinds of matter Descartes believes one needs for a physical theory of light, and become unashamedly hypothetical by the end of the chapter, where Descartes tells us that he is going to 'wrap his discourse up in the cloak of a fable'.

Chapter 6 begins with Descartes' construction of a hypothetical world on the basis of the theory of matter set out in the first five chapters. The ultimate aim is to show that a world constructed in this manner, one without forms or qualities, is indistinguishable from the actual world. The traditional forms and qualities are excluded because they could not form part of a properly mechanist explanation. The task of the first five chapters has been to set out the kind of entities and properties that he wants to invoke in his account, and he has prepared the ground by trying to show that they have the requisite qualities of clarity and evidence. If we strip the world of the traditional forms and qualities, what we would be left with would, in Descartes' view, be its genuine properties. His new world is to be conceived as 'a real, perfectly solid body which uniformly fills the entire length, breadth, and depth of the great space at the centre of which we have halted our thought'. This perfectly solid body is 'solid' in the sense of being full and voidless, and it is divided into parts distinguished simply by their different motions. At the first instant of creation, God provides the parts with different motions, and after that He does not intervene supernaturally to regulate their motions. Rather, these motions are regulated by laws of nature which Descartes now sets out.

These laws of nature are designed to describe the collisions of corpuscles. In imagining such collisions, it is tempting to picture them in terms of atoms colliding in a void, but we must exercise care in allowing ourselves to think in these simplified terms, for we naturally think of atoms moving in a void as continuing for long stretches without collision, whereas for Descartes there is constant collision. This is important because the counterfactual situation in which a body moves in the absence of external constraints is not so immediately relevant to Descartes' analysis as it would be to a straightforwardly atomistic account, where the obvious way to proceed would be from the simple case of unconstrained motion to how the motion is changed by various constraints. This is the essence of the kinematic approach,[13] but it is far from clear that Descartes' approach is kinematic. His model seems rather to be taken from hydrostatics, and the point seems to be not so much to analyse the behaviour of a body under various kinds of constraint in terms of how it behaves when not under constraint, but rather to account for what happens when a body moves from one system of constraints to another, where the constraints that Descartes is interested in are collisions.

The three laws of nature that Descartes provides are designed to

[13] See, for example, Galileo's brilliant kinematic analysis of falling bodies in terms of motion in a void, in the second half of the 'First Day' of his *Two New Sciences*, published in 1638.

describe the behaviour of bodies in collision. They deal quite separately with the power of moving and the determination of a body. The first law tells us that a body conserves its motion except in collision, when, the second law tells us, the total motion of the colliding bodies is conserved but may be redistributed amongst them. It is left to the third law to tell us about direction, and according to this law, because a body's tendency to move is instantaneous, this tendency to move can only be rectilinear, because only rectilinear motion can be determined in an instant: 'only motion in a straight line is entirely simple and has a nature which may be grasped wholly in an instant'. Motion in a circle or some other path would require us to consider 'at least two of its instants, or rather two of its parts, and the relation between them'. What path the body will actually take, however, will be a function of the collisions to which it is subject.

The first law states that certain states of bodies are conserved: they will remain unchanged unless something acts to change them. Among these are a body's size, shape, its position if it is at rest, and also its motion, for once a body has begun to move, 'it will always continue in its motion with an equal force until others stop or retard it'. This rule of conservation of state has always been considered to hold for the first three items, and many others, Descartes tells us, but not for the last, 'which is, however, the thing I most expressly wish to include in it'. In defence of the first law, Descartes spells out the conception of motion that it employs and contrasts this with the Aristotelian conception. His suggestion is that motion is simply to be equated with change of place or translation.

The second law of motion is a law of the conservation of motion (or perhaps a law of conservation of the total 'force of motion') in collisions. In its defence, Descartes points to its advantages over the traditional accounts of continued projectile motion. Aristotelians were in disagreement amongst themselves about how to account for the continued motion of projectiles, and their accounts were premised upon a distinction between terrestrial and celestial motions. Descartes changes the question, so that it now becomes that of explaining why the motion of the projectile decays rather than why it continues to move, and the answer he provides is the air's 'resistance'.

When he sets out the second law he talks about motion being conserved, but in subsequent elaboration he reformulates it in terms of conservation of 'force of motion'. Because of the problems in separating out what exactly is physical and what is divine in Descartes' account of causation and force, it is difficult to say whether causation is something physical, or whether it has both a divine manifestation and a physical manifestation in the form of force of motion, or whether force of motion is a physical expression of something that is non-physical.[14] But whichever of these we opt for, motion is conserved because force of motion is conserved, and force of motion in some way expresses or manifests God's causal activity. It is ultimately because causation is conserved – a conservation that Descartes puts in terms of God's immutability – that motion is conserved.

Whereas the first two laws deal with the power of motion, the third deals with what Descartes regards as a separate issue: the direction of motion. It asserts that, whatever the path of a moving body, its tendency to motion, or *action*, is always rectilinear. The evidence presented for this is (i) that a stone released from a sling will not continue to move in a circle but will fly off along the tangent to the circle, and (ii) while in the sling the stone will exert a force away from the centre causing the string to stretch, showing 'that it goes around only under constraint'. But there is a notorious discrepancy in Descartes' account here. The trouble is that while the third law as stated in chapter 7 would seem to establish the uniqueness of rectilinear motion as an inertial motion, when he elaborates further on the law in chapter 13 he apparently counts a circular component in the motion of the stone as inertial as well. Why, after giving a clear statement of rectilinear inertia and providing an explanation of why rectilinear motion is the only inertial motion in terms of its 'simplicity', does he appear to blatantly contradict this? There are two complementary answers to this question, I believe, and both derive from Descartes' attempt to use the hydrostatic model in his physical theory. The first is that a statement of a principle of inertia does not seem to be the main point of the exercise. He does not seem particularly concerned to specify how a body behaves in the absence of forces, for example, because the bodies he deals with always move within a system of constraints, just as in statics: the aim is to understand the instantaneous collisions of non-elastic bodies. One does not ask what would happen if the forces were removed, because the understanding of the action of these forces is the point of the exercise. The second is that what Descartes is concerned with in chapter 13 is not so much circular inertia as circular equilibrium, namely, the idea that a body moves in a continuous

[14] See M. Gueroult, 'The metaphysics and physics of force in Descartes', in S. Gaukroger (ed.), *Descartes: Philosophy, Mathematics and Physics* (Brighton, 1980), 196–229, *passim*, and Gabbey, ibid., 234–9.

circular orbit because the forces acting upon it are exactly balanced, so that the net force is zero. The confusion arises because Descartes slides between this static notion of equilibrium (which involves the extremely problematic assumption that some motions are dynamically unbalanced) and the dynamic notion of inertia.

Chapters 8 to 12, using the theory of matter and laws of nature which have now been elaborated, set out the details of a heliocentric cosmology in the form of an account of a hypothetical 'new world', from the formation of the Sun and the stars (ch. 8), the planets and comets (ch. 9), the Earth and the Moon (ch. 10), and finally weight or gravity (ch. 11) and the tides (ch. 12). The key to this whole cosmology is Descartes' account of vortices. Because the universe is a plenum, for any part of it to move it is necessary that other parts of it move, and the simplest form of motion which takes the form of displacement is going to be a closed curve, although we have no reason to think that the universe turns around a single centre: rather, we may imagine different centres of motion. The matter revolving furthest away will be the largest or most agitated because it will describe the greatest circles, owing to its greater capacity to realise its inclination to continue motion in a straight line. Whatever differences in size and agitation we may imagine there to have been in the early stages of the universe, however, except for the large clumps of third element we can imagine that the constant motion and collision caused the difference in sizes of matter to be reduced as 'the larger pieces had to break and divide in order to pass through the same places as those that preceded them'. Similarly, differences in shape gradually disappear as repeated collisions smooth off the edges and all matter (of the second element) becomes rounded. Some pieces of matter are sufficiently large to avoid being broken down and rounded off in this way: these are what Descartes refers to as the third element, and such pieces of matter form the planets and the comets. Finally, the collisions yield very small parts of matter, which accommodate themselves to the space available so that a void is not formed but this first element is formed in a greater quantity than is needed simply to fill in the spaces between pieces of second and third element, and the excess naturally moves towards the centre because the second element has a greater centrifugal tendency to move to the periphery, leaving the centre the only place for the first element to settle. There it forms perfectly fluid bodies which rotate at a greater rate than surrounding bodies and exclude fine matter from their surfaces. These concentrations of first element in the form of fluid, round bodies at the centre of each system are suns, and the pushing action at their surfaces is 'what we shall take to be light'.

The universe, as Descartes represents it, consists then of an indefinite number of contiguous vortices, each with a sun or star at the centre, and planets revolving around this centre carried along by the second element. Occasionally, however, planets may be moving so quickly as to be carried outside the solar system altogether: then they become comets. Descartes describes the difference between the paths of planets and comets in terms of an engaging analogy with bodies being carried along by rivers, the latter being like bodies that will have enough mass and speed to be carried from one river to another when rivers meet, whereas the former will just be carried along by the flow of their own river. Planets eventually enter into stable orbits, the less massive they are the closer to the centre, and once in this orbit they are simply carried along by the celestial fluid in which they are embedded. The stability of their orbits arises because, once a planet has attained a stable orbit, if it were to move inward it would immediately meet smaller and faster corpuscles of second element which would push it outward, and if it were to move outward, it would immediately meet larger corpuscles which would slow it down and make it move inward again.

This accounts for the motions of comets and the motion of planets proper around the Sun, and Descartes now moves on to explain the motions of planetary satellites and the diurnal rotation of a planet like the Earth. The celestial matter in which the Earth is embedded moves faster at one side of the planet than at the other, and this gives the Earth a 'spin' or rotation, which in turn sets up a centrifugal effect, creating a small vortex around itself, in which the Moon is carried. Turning next to consider what the weight (*pesanteur*) of the Earth consists in, Descartes rejects the idea of weight as an intrinsic property. In earlier writings he had defined weight in functional terms as 'the force of motion by which a body is impelled in the first instant of its motion' (AT x. 68). It is not surprising, therefore, that he has no hesitation in offering a similar account here.

Finally, the phenomenon of the tides is explained using the same materials. Direct evidence for the orbital and rotational motion of the Earth was not available in the seventeenth century, but the tides, which are difficult to explain on the assumption of a non-rotating Earth, do offer indirect evidence. Tides are a very complicated phenomenon, however, involving daily, half-monthly, monthly, and half-yearly cycles. Descartes was especially pleased with his account and wrote to Mersenne at the time that accounting for the tides had given him a great deal of trouble, and that while he was not happy with all the details, he did not doubt the success of his account (AT i. 261). And although he will revise it over the next ten years, he will not alter its fundamentals. Indeed, the theory of the tides is really the first genuinely quantitative ingredient in the *Treatise on Light*, but the fact that the earlier material is not quantitative should not blind us to the significance of Descartes' success in presenting a thoroughly mechanist cosmology which takes as its foundations a strictly mechanist conception of matter and the three laws of motion. The *Treatise on Light* presents a fully mechanist alternative to Aristotelian systems, one which effectively derives heliocentrism from first principles, which offers a novel and apparently viable conception of matter, and which formulates fundamental laws of motion – laws that are clearly open to quantitative elaboration. But the jewel in the crown of *Treatise on Light* is the theory of light set out in the last three chapters, for, especially if we read these together with Descartes' general work in optics at this time, we have an empirical, quantitative account of a physical question whose explanation derives directly from his mechanist cosmology.

Descartes' purpose in the last three chapters is to show how the behaviour of light rays can ultimately be explained in terms of his theory of the nature of matter and the three laws of motion. Indeed, the theory of matter turns out to be motivated directly by the requirements of Descartes' physical optics, for the first element makes up those bodies that produce light, namely suns and stars; the second element makes up the medium in which light is propagated, namely the celestial fluid; and those bodies that refract and reflect light, such as the planets, are made up from the third element. Moreover, it is the laws of motion that underpin and explain the laws of refraction and reflection of light, and the accounts of phenomena such as the rainbow and parhelia that are based on these.

The laws of motion show us that, given the rotation of the Sun and the matter around it, there is a radial pressure which spreads outwards from the Sun along straight lines from its centre. This pressure is manifested as 'a trembling movement', a property which is 'very suitable for light'. Indeed, the inhabitants of Descartes' proposed new world 'have a nature such that, when their eyes are pushed in this way, they will have a sensation which is just like the one we have of light'. The question that Descartes now poses is whether this model accounts for the known properties of light. Setting out twelve 'principal' properties of light which a theory of light must account for he proceeds to show that his account is not only compatible with all of these, but can actually explain them.

Descartes' achievement in the *Treatise on Light* is twofold. In the first place, his vortex theory explains the stability of planetary orbits in a way that presents an intuitively plausible picture of orbital motion which requires no mysterious forces acting at a distance: the rapid rotation of the Sun at the centre of our solar system, through its resultant centrifugal force, causes the 'pool' of second matter to swirl around it, holding planets in orbits as a whirlpool holds bodies in a circular motion around it. Moreover, it explains this motion in terms of fundamental quantifiable physical notions, namely centrifugal force and the rectilinear tendencies of moving matter. In other words, the heliocentric theory is derived from a very simple theory of matter, three laws of motion, and the notion of a centrifugal force. Secondly, this account also enables Descartes to account for all the known principal properties of light, thereby providing a physical basis for the geometrical optics that he had pursued so fruitfully in the 1620s.

The *Treatise on Man*

Just as the strategy behind the *Treatise on Light* was to construct an 'imaginary world' out of the basic materials supplied by mechanism, and then show that such a world is indistinguishable from the real one, so too the *Treatise on Man* begins with an imaginary mechanistic world, the aim being to show how a physiology can be constructed out of it which is indistinguishable from real animal physiology. The physiology he describes is not original, being derived from a number of sources including Hippocrates, Galen, Scholastic commentators on biology and medicine, especially the Coimbra commentators, and various sixteenth- and seventeenth-century writers on biological and medical topics.[15] The originality comes in the attempt to show how such a physiology can be modelled mechanistically. In particular, various functions had traditionally been ascribed to qualitatively different 'souls': digestion, movement of the

[15] For details see Annie Bitbol-Hespériès, *Le Principe de vie chez Descartes* (Paris, 1990). Hippocrates (c.460–c.377 BC) is widely regarded as the founder of medicine. Galen (c.130–c.210) is the most important author on anatomy and physiology before Versalius and Harvey respectively. The Coimbra commentators were a group of Jesuit philosophers based at Coimbra in Portugal who produced huge commentaries on Aristotle in the last decades of the sixteenth and early seventeenth centuries. Their works were standard in Jesuit colleges, and Descartes was taught from them.

blood, nutrition, growth, reproduction and respiration to the 'vegetative soul'; perception, appetites and animal motion to the 'sensitive soul'. Descartes sets out to show how we need postulate no souls at all for these organic processes, that all that is needed is the right kind of mechanical explanation.

In Part 1, for example, the digestion of food is described in a mixture of mechanical and chemical terms, and the cause of the circulation of the blood is put down to the production of heat in the heart, the thermogenetic processes causing pressure in the arteries. The blood carries animal spirits, which are separated out from the blood by a simple filtration process and enter the brain through the pineal gland. In Part 2, he sets out how the nervous system works by means of the animal spirits, which enter the nerves and change the shape of the muscles. It is worth remembering in this context that Descartes' mechanistic model is not that of a clock, but one of hydraulic systems, such as those that worked the fountains and moving statues in the gardens of Saint-Germain. Just as in the *Treatise on Light*, where bodies are carried along in fluids, so here the kind of image Descartes' model conveys is that of fluids being pushed through tubes, not wheels working cogs, and this has a much more intuitively 'organic' feel, something that Descartes' critics have often overlooked when assessing the general plausibility of his account.

A crucial discussion in Part 2 is that of the action of the pineal gland, which is also responsible for the discharge of the animal spirits to the muscles via the nerves. Take the case of an animal spotting a predator and escaping. Physiologically, what happens is that external stimuli – smells and visual stimulation – displace the peripheral ends of the nerve fibres in the nose and eyes, and structural isomorphs of the sense impressions are transmitted to the brain, unified into a single isomorph in the 'common sense' (which unifies isomorphs from the various senses into a unitary image), and form an 'idea' – a change in the pattern formed by the animal spirits on the surface of the pineal gland. Such a changed pattern results in changes in the outflow of spirits to the nerves. At the muscle, a small influx of spirit from the nerve causes the spirits already there to open a valve into its antagonist. Spirits then flow from the antagonist which causes it to relax, as well as causing the first muscle to contract. Escape from the predator is thereby facilitated. Note, incidentally (a fact overlooked by very many commentators), that this is *not* an account of reflex action, which is described at the end of Part 2, for reflex action is a more primitive operation which does not even involve the pineal gland since it does not require a representation of the stimulus but a direct response: the reflex arc (see fig. 38) passes through what Descartes refers to as a 'cavity' (labelled F), a term which he never uses for the pineal gland and which almost certainly refers to one of the cerebral ventricles.

In Part 3, which deals with sense perception, we are offered quite a sophisticated account of distance vision. Here Descartes deals with a particularly pressing problem for a mechanistic account of vision. The mechanist allows only contact actions, so the surface of the eye only has contact with the light corpuscles that strike it, but such corpuscles cannot carry information about their origins, for example, about the distance of their source. How, then, is distance perception possible? Descartes' ingenious solution is to suggest that our cognitive apparatuses (not our minds, for animals are capable of distance perception and they lack minds in the strict sense) are able to operate with an innate 'natural geometry' by which one can judge the distance of an object in virtue of knowing the distance between the eyes and the angle at which light corpuscles strike the eyes, this giving us the base angles and base length of a triangle, from which we can gauge the distance of the apex from the base by elementary trigonometry.

Part 4 is concerned with internal psycho-physiological operations, and here we are presented with a range of accounts of very different degrees of sophistication and plausibility. At one extreme is the account of personality traits such as generosity and liberality, which are put down to an abundance of animal spirits. At the other is an account of memory which mirrors the concerns of his account of perceptual cognition. In the latter case, Descartes is concerned to argue that perception does not involve resemblance, but it does involve representation. He now applies these considerations to memory, showing that memories need not resemble the event of which they are the memory: they need only encode the information in such a way that we can bring that event to mind in the absence of any external stimulus. Pineal patterns do not have to be kept in the same form between experiencing and remembering, and this has ramifications for the question of how memories are stored and retrieved, which steers Descartes' account, which is essentially a dispositional account, in a completely different direction from that of his predecessors and contemporaries, who were concerned with the question of the localisation of memory.[16]

[16] For details see John Sutton, *Philosophy and Memory Traces* (Cambridge, 1998).

The *Treatise on Man* reads like a complete treatise – the last sentences sum up the main thrust of the *Treatise* and have the air of a conclusion – but there are omissions, and we might have expected the argument that the mechanical devices constructed are indistinguishable in their operations from animal physiology to have been put, and a transition made to Part III, that is, to the case of human beings. The psycho-physiology (as just described) is regulated by a mind – most importantly the ability to make judgements and exercise free will – in the case of human beings, and this makes a crucial difference to the nature of their cognitive states, and it is a great pity that Descartes does not go on to spell out the nature of this difference. The situation is complicated by the fact that the *Treatise on Man* was worked on into the 1640s, however, for it may have become independent of the originally planned third part of the project.

The abandonment of *The World*

At the time that Descartes began working on *The World*, Galileo was putting the finishing touches to his *Dialogue Concerning the Two Chief World Systems*, to which he had devoted much of his time between 1624 and 1630. The work was withdrawn shortly after its publication in Florence in March 1632, however, and it was condemned by the Roman Inquisition on 23 July 1633.

The *Dialogue* provided physical evidence both for the Earth's diurnal rotation, in the tides, and for its annual orbital motion, in cyclical change in sunspot paths. It also provided a detailed and ingenious account of why our perceptual experience apparently does not accord with the Earth's motion, in the principle of the relativity of motion. Although Galileo was powerfully connected and was widely celebrated for his discovery of the moons of Jupiter in 1610, he had been warned of his responsibility to treat the motion of the Earth hypothetically by the Florentine Inquisition as early as 1616. This earlier condemnation, as well as that of 1633, focused on the question of the physical reality of the Copernican hypothesis. A core issue in dispute in both the 1616 and 1633 condemnations of Copernicanism was whether the heliocentric theory was 'a matter of faith and morals' which the second decree of the Council of Trent had given the Church the sole power to decide.[17] Galileo and his defenders denied that it was, maintaining that the motion of the Earth and the stability of the

[17] For details see Richard J. Blackwell, *Galileo, Bellarmine, and the Bible* (Notre Dame, 1991).

Sun were covered by the first criterion in Melchior Cano's handbook of post-Tridentine orthodoxy, *De locis theologicis*, namely that when the authority of the Church Fathers 'pertains to the faculties contained within the natural light of reason, it does not provide certain arguments but only arguments as strong as reason itself when in agreement with nature'. Opponents of Galileo argued that the case was covered by different criteria, such as the sixth, which states that the Church Fathers, if they agree on something, 'cannot err on dogmas of the faith'. In the 1633 condemnation, the latter interpretation was effectively established, and this meant that the physical motion of the Earth could not be established by natural-philosophical means. Thus the kind of arguments that Galileo had offered in the *Dialogue* not only had no standing in deciding the issue, but also the kind of arguments that Descartes had offered in the *Treatise on Light* had no such standing either.

At the end of November 1633, Descartes wrote to Mersenne:

> I had intended to send you *Le Monde* as a New Year gift . . . but in the meantime I tried to find out in Leiden and Amsterdam whether Galileo's *World System* was available, as I thought I had heard that it was published in Italy last year. I was told that it had indeed been published, but that all copies had been burned at Rome, and that Galileo had been convicted and fined. I was so surprised by this that I nearly decided to burn all my papers, or at least let no one see them. For I couldn't imagine that he – an Italian and, I believe, in favour with the Pope – could have been made a criminal, just because he tried, as he certainly did, to establish that the earth moves . . . I must admit that if this view is false, then so too are the entire foundations of my philosophy, for it can be demonstrated from them quite clearly. And it is such an integral part of my treatise that I couldn't remove it without making the whole work defective. But for all that, I wouldn't want to publish a discourse which had a single word that the Church disapproved of; so I prefer to suppress it rather than publish it in a mutilated form. (AT i. 270–1)

Descartes was clearly devastated by the condemnation, and he abandoned any attempt to publish *The World* as a result.[18] The outcome of this

[18] That it was indeed the condemnation of Galileo that prevented publication, and not his corpuscularianism or animal automatism, as have occasionally been suggested, is clear from the letter to Mersenne just quoted, and also from his request to Mersenne to tell Naudé that the only thing stopping him publishing his physics was the prohibition on advocating the physical reality of the Earth's motion. Descartes to Mersenne, December 1649; AT iii. 258.

crisis was a new direction in his work. Although he does not abandon interest in natural philosophy, and to the end of his life continues to think it has been his most important contribution,[19] this interest in it is now confined largely to polemics and systematisation, and above all to the legitimation of a mechanist natural philosophy by metaphysical and epistemological means,[20] a completely different enterprise from that pursued in *The World*.

The optical material in *The Treatise on Light* was to appear in the *Dioptrics* and *Meteors* (both 1637), shorn of all contentious cosmological material; the cosmological material, buttressed by metaphysical arguments and with a protective hypothesis which purported to show that all motion is relative (and so allowing one to hedge one's bets on the physical reality of a heliocentric system) appeared in the *Principles of Philosophy* (1644). As regards the physiology of the *Treatise on Man*, very basic outlines of the physiology were presented at the beginning of the *Passions of the Soul* (1649), but, other than that, nothing appeared in Descartes' lifetime. There are manuscript notes on anatomy, physiology, and embryology dating from the 1630s and early 1640s, and a much more significant piece called *Description of the Human Body* dating from the winter of 1647–8. The first three parts of this latter work update the *Treatise on Man*, and Descartes rejects Harvey's account of the pump action of the heart, preferring his own thermogenetic account as an explanation of the cause of circulation. In the fourth and fifth parts, new material on the development of the embryo is introduced. This is very important material, as the kinds of process involved in the formation of the foetus are far more intractable, from the point of view of a mechanist physiology, than basic adult physiology, and Descartes has to account for these processes purely in terms of his theory of matter. Indeed, the two crucial problem areas for a mechanist physiology are psycho-physiology and the formation of the foetus: both areas are constituted by what are apparently goal-directed activities – cognition in the one case, and growth from a relatively undifferentiated small mass of material to a complex organism in the other – and they offer an immense challenge to a mechanist account.

[19] See the passage in the conversation with Burman, given at AT v. 165, where Descartes warns against devoting too much time to metaphysical questions, especially to his *Meditationes*. These are just preparation for the main questions, which concern physical and observable things. Cf. Descartes to Elizabeth, 28 June 1643; AT iii. 695.

[20] This shift in direction of Descartes' thought is discussed in the detail in chs. 8 and 9 of Gaukroger, *Descartes: An Intellectual Biography*.

Descartes' treatment of the first is a triumph of sophistication and ingenuity; his treatment of the second is far more tentative, and much less successful, but he does make a sustained effort to come to terms with the problems.

The material on the soul in the projected third part of *The World*, which I have indicated was probably not even drafted as such at the time, but which would almost certainly have drawn on the lost 'Treatise on Metaphysics', took on a life of its own, so to speak, in the legitimatory epistemological–metaphysical project of the post-*Le Monde* period. One can properly raise the question whether this project yields its fruit in the radical dualism of the *Meditations* or in the rather more naturalistic account of mind in the *Passions of the Soul* (which begins with a summary of the *Treatise on Man*). The latter is suggested by structural reasons. The *Treatise on Light*, which deals with physics and cosmology, was followed by the *Treatise on Man*, which dealt with animal physiology, and was to be followed by a treatise on the soul. The four books of the *Principles of Philosophy* follow the structure of the *Treatise on Light*, albeit now the account is formulated in the context of a foundationalist metaphysics, in which dualism plays an integral role. The projected fifth book of the *Principles* was on 'living beings' and I think there can be no doubt that the *Description of the Human Body* is the draft material for that part. The *Passions of the Soul*, which offers a relatively naturalistic account of affective states,[21] employing Descartes' idea of a 'substantial union of mind and body' rather than the radical dualism of his foundational projects, seems to be the projected sixth part, on 'the soul'.

The World provides us with an alternative to the *Meditations* as an entry into Descartes' thought. Whereas in the *Meditations* we are led to natural philosophy through the sceptically driven epistemology on which Descartes grounds a metaphysically formulated natural philosophy, in *The World* we are offered a more direct access to the whole of natural philosophy, from cosmology to cardiology to the psycho-physiology of perception. If we take the latter route we are in a better position to assess the role played by, and any benefits to be derived from, the epistemological and metaphysical underpinning that Descartes provides for his natural philosophy in his later writings.

[21] The account is quite at odds with the radical dualism advocated in the metaphysical context of the *Meditations* (at least up to Meditation 5: in Meditation 6 Descartes tries to mitigate his radical dualism), and is much closer to the naturalistic account of cognitive states offered in the *Rules for the Direction of the Native Intelligence* and the *Treatise on Man*.

Chronology

1596	Descartes born at La Haye (now Descartes) near Tours
1606	Begins as a boarder at the Jesuit college of La Flèche
1614–15	Leaves La Flèche and moves to Paris
1615–16	Studies law, and perhaps some medicine, at the University of Poitiers, taking his baccalauréat and licence in civil and canon law in November 1616
1618	Joins the army of Prince Maurice of Nassau. Meets Isaac Beeckman, who rekindles his interest in scientific matters. Writes *Compendium Musicae*
1619	Begins the year working intensively on mathematical and mechanical problems under Beeckman's encouragement and guidance. Extant writings from this period include fragments on the mathematical description of free fall, and the hydrostatic paradoxes, which represents Descartes' first excursion into micro-mechanical explanation. Early in 1619 he studies proportional compasses, and begins to formulate a theory of proportional magnitudes which will ultimately lead him in the direction of algebra. He spends the later part of the year stationed at Ulm. Here he begins to formulate a general theory of method
1620	Begins work on his *Rules for the Direction of the Native Intelligence*, completing the first eleven Rules, then abandoning the project. In the course of 1620 he works intensively in geometry, and discovers some fundamental results in co-ordinate geometry
1625–6	Settles in Paris, and works on geometrical optics: he may have discovered the law of refraction as early as 1626