Chapter 9

# The new science

## Physics, physiology, and the passions

Descartes was a mathematician and natural philosopher before he was a metaphysician. From about 1630 on, he envisioned a new, comprehensive science of nature, the construction of and justification for which became his primary aim. The *Meditations* was to provide the promised metaphysical foundations for the new system.

To understand the role of the *Meditations* in establishing foundations for physics, we need to appreciate the scope of Descartes' physics. Physics today is far removed from "the world of nature," if under that term we imagine mineral formations, plants, and animals. The science of physics studies nature at very small (subatomic) or very large (astronomical or cosmic) scales. Other natural sciences, including chemistry and biology, study things at or near the scale of living things. The mental world is now often placed in opposition to the physical and natural worlds; psychology (the study of mental life) is only sometimes called a natural science.

In Descartes' day, "physics" or "natural philosophy" meant simply "the science of nature." "Nature" encompassed everything having a nature or essence (at least on the Earth), including human beings and human cognition. Aristotelian works on psychology (including *De anima*, "On the Soul," as well as works on dreams, memory, and the senses) were classed within physics. Descartes conceived of physics in this broad sense. He included animal and human physiology, and even the *Passions of the Soul* (11:326), within physics. While he wasn't clear on whether the human mind considered by itself fell within physics, he was clear that mind–body union and interaction were part of physics or the science of nature. Although affirming mind–body substance dualism, he did not take that position to imply that the embodied mind is somehow unnatural, or supernatural, or beyond natural science. It was not Descartes' intent to exclude mind from nature through his dualism.

All the same, Descartes' philosophy did realign the relation between mind and matter and offered a revolutionary conception of matter itself (by contrast with Aristotelian philosophy). It reduced matter to extension, leaving it no properties beyond the geometrical modes of extension: size, shape, position, and motion. This reconception changed the way living things could be conceived. Descartes thought of plants and animals as machines, denying them the active principles and cognitive powers found in Aristotelian physiology and psychology. In Descartes' mechanistic physiology, all bodily processes are viewed as interactions between particles according to the laws of motion. He extended the notion of lawful regularity to mind–body interaction, positing a permanent relation between brain states and the sensations, appetites, and emotions they produce in the mind. For him, there was no conflict between dualism and psychophysical laws.

In this chapter, we will examine Descartes' physics from its foundations as provided in the *Meditations* (and elaborated in the *Principles*). The broad conception of physics permits us to see how various Meditations provide foundations for physics that would not be apparent under the narrower, present-day conception. We can include among the "physical" topics not only the new concept of matter from Meditations 2, 3, and 5, and God's role in preserving that matter, but also the analysis of mental faculties from Meditation 2, and human physiology and mind–body interaction from Meditation 6.

## Descartes' revolution in physics

The sixteenth and seventeenth centuries saw rapid intellectual change in Europe. The Aristotelian philosophy – dominant from the thirteenth through the sixteenth centuries – was replaced by new philosophies, including new philosophies of nature. Many factors contributed to this development. Aristotelianism itself had changed over the centuries and was challenged by the revival of Platonic philosophy in the fifteenth century. It survived the challenge, although in the sixteenth century syntheses of Plato and Aristotle became common. In medicine and physiology, Aristotelian viewpoints had been combined with Galenic anatomy and physiology (Galen was a second-century physician in Alexandria, Egypt). The Italian anatomist Andreas Vesalius revivified the study of anatomy through the publication of carefully prepared anatomical drawings based on dissection of human corpses. In astronomy, Copernicus combined the ancient standards of mathematical exactness with the desire for a coherent account of planetary motions, arguing that the Earth moves around the Sun (opposing the Earth-centered cosmos of Aristotle and of Ptolemy, a second-century Egyptian). In optics or the theory of vision, the geometrical, intromission theory of Ibn al-Haytham, an eleventh-century Islamic philosopher, was made available in a sixteenth-century Latin translation, which spurred new work. In natural philosophy proper, ancient Greek atomistic theories of matter were revived and discussed.

Early in the seventeenth century, demand intensified for a "new science" of nature, and for a new philosophy to frame it. Francis Bacon called for a reformed science, based on greater attention to direct observation of nature, including observations made by artisans and skilled craftsmen. Galileo defended the Copernican system in astronomy through arguments against the assumptions of Aristotelian physics and Ptolemaic astronomy, and with his telescopic observations of the moons of Jupiter (thus questioning Earth's uniqueness as a body about which other bodies revolve). He developed a new science of motion (including a law describing the acceleration of freely falling bodies). Kepler developed Copernican planetary astronomy and combined al-Haytham's optical theory with a new understanding of the internal anatomy of the eye. William Harvey proposed that the blood is pumped through the body so that it circulates several times per hour (as opposed to previous theories that blood slowly oozes and does not circulate).

These key developments in the "Scientific Revolution" all occurred prior to 1633, the year in which Descartes completed his *World*. Yet none of the authors mentioned proposed anything to rival the comprehensiveness of Descartes' new vision of nature, as presented in his *World* and *Principles*. The earlier innovators made important theoretical proposals in single areas of science, or, in Bacon's case, proposed a new method intended to generate, at some point, a comprehensive new theory of nature. Descartes, in addition to making individual discoveries and offering a new method, proposed a comprehensive new theory. He was the first to present a wide-ranging new system of nature, and that system was developed and elaborated by his followers for more than fifty years after his death before being displaced by Newton's physics.

### *Overview of Aristotelian physics*

The radical nature of Descartes' proposals is best understood against the background of the prevailing Aristotelian physics. A common Aristotelian position held that natural bodies are a composite of form and matter, and that matter could not exist without form. The form of a thing determined its nature or essence. Forms were principles of growth and change; they literally made things "be what they are" by directing the development and activity of matter toward an end (hence away from any lack or "privation" of that end). Nature was divided into a variety of kinds of substance, each with its characteristic pattern of activity. All bodies were thought to be composed of the four elements: earth, air, fire, and water. In these elements, undifferentiated matter takes on the forms of the four basic qualities: hot, cold, wet, and dry. Earth is cold and dry, air hot and wet, fire hot and dry, and water cold and wet. Other qualities, such as color and odor, also exist as forms that can be transmitted from bodies to the sense organs.

Higher-level natural kinds were divided into mineral, vegetable, and animal. In complex or "mixed" bodies (mixtures of elements), the four elements served as the "matter," and a kind-specific form gave each type of thing its characteristic pattern of activity. Thus, crystals or metals derive their properties from their forms (of quartz, gold, etc.). The oak tree grows as it does because its form (contained in the acorn) directs that growth. Similarly for the various kinds of animals, including the human animal. Each has a characteristic form, introduced into the reproductive "matter" of the female by the male during procreation, which directs its growth and activity. Certain powers or activities of this form are similar across animal species – all animals have nutritive, locomotive, and sensory powers. The form of the human animal also possesses a rational power, as its defining or essential power. The forms of all natural things direct them toward their natural end, whether the center of the universe (in the case of the earthy element), or knowledge and wisdom (in the case of a human being, the rational animal). In this way, Aristotle's physics compared all natural processes to the biological process of growth.

Aristotelian physics strictly divided the heavens from the Earth. The natural tendency of the earthy element to seek the center of the universe fixes the Earth in that location. Water has the same tendency, although less strongly, and so collects on the surface of the Earth. Air and fire have upward tendencies, the second stronger than the first. These four elements are found in the region of change, extending up to the sphere of the Moon (which acts as a bubble around the Earth). The Moon, Sun, planets, and "fixed stars" (an outermost bubble) are carried around the Earth, embedded in crystalline spheres. These spheres are not composed of the four elements but of a fifth element, the quintessence ("quint" means fifth), which is unchanging. The region above the sphere of the Moon, including the Sun and planets, was considered to be unchanging, with the heavenly bodies revolving around the Earth in uniform circular motion (which did not count as "change" or "alteration" in an Aristotelian sense).

To account for the apparently irregular motions of the planets, uniform circular motions had to be compounded by adding additional spheres.

To gain acceptance for his own physics, Descartes needed to break the hold of Aristotelian physics on common sense. Aristotelian physics says that for a body to keep moving, force must be constantly applied. This accords with much of our everyday experience. Descartes' laws of motion say that a body moving in a straight line will continue in motion unless hindered. Aristotelian physics says that earthy matter naturally moves toward the center of the universe (and of the Earth). Descartes says that invisible subtle matter, swirling in a vortex around the Earth, pushes objects downward. Aristotelian physics says that each natural kind contains a substantial form that serves to produce its characteristic activities, including the growth and development of living things. Descartes says that the various natural kinds differ only in the sizes, shapes, positions, and motions of their particles, and that animal bodies are mere machines. Aristotelian physics says that objects have the properties they appear to have, in the manner in which they appear to have them – that color, odor, and so on are real qualities encountered in sensory experience. Descartes says that, in objects, these qualities are really configurations of corpuscles that, in the case of color, induce spin in particles of light and ultimately cause a color sensation in the mind.

Descartes sought acceptance for a (then) counter-intuitive picture of nature. We may find it difficult to appreciate the full force of his problem, since his vision of nature has been partly retained, and it informs today's common sense.

### *Descartes' new system*

In developing his new physics, Descartes drew upon the empirical results and theoretical proposals of previous authors, including the optical work of al-Haytham and Kepler, the astronomical arguments of Copernicus and Galileo, the circulatory theory of Harvey, and the revival of ancient atomism. But he moved beyond these results by proposing a new conception of homogeneous extended matter governed by a few laws of motion.

Although Copernicus and Galileo had challenged ancient physics and astronomy, neither offered a new system of physics to encompass both heavens and Earth. Descartes' physics did just that, by appealing only to particles in motion to explain all phenomena throughout the material world – including the formation of the Sun and solar system, the revolution of the planets around the Sun (carried along by a whirling vortex of subtle matter), and, in principle, everything observable in the heavens and on Earth. Descartes used his new conception of matter in framing comprehensive and detailed theories to explain the known phenomena of light, heat, fire, weight, magnetism, various minerals, and the physiology of living things. His proposed explanations were often quite fanciful, such as the explanation of magnetism by corkscrew-shaped particles flowing out from the poles of the Earth, circulating north and south, and entering the opposite pole while passing through the threaded channels in any magnetic bodies encountered along the way – with left- and right-hand threading accounting for opposite polarity (8A:275–310). These explanations were unified in that they appealed only to the properties of size, shape, position, and motion. The role of Descartes' metaphysics was to show that these are the only properties of matter, and hence must frame all explanatory hypotheses concerning the material world.

We saw in Chapter 1 that Descartes developed his comprehensive new theory during 1629–33, as he composed his *World*. This period began with the "metaphysical turn" of 1629–30, during which he claimed to have discovered the foundations of physics while thinking about God and the soul (1:144). We can appreciate more fully how this might have happened by comparing two strategies Descartes used in justifying his new philosophy of nature. When offering a sample of his new physics in the *Discourse* and essays, he did not present a metaphysical justification for its basic principles. He put forward as a hypothesis that bodies are composed of particles having only the properties of size, shape, position, and motion. The *Discourse* argues that this corpuscularian hypothesis is confirmed by the wide range of effects it could explain (6:76). In effect, it offers an empirical argument from explanatory unity in support of the new physics.

During this same period, Descartes also promised a metaphysical demonstration for the basic principles of his physics (6:76). In letters from 1638, he further elaborated the empirical argument but refused to reveal the metaphysical demonstration (1:563–4, 2:199–200). He mentioned both types of argument in a letter to the French mathematician J.B. Morin, comparing his explanations with those of the Aristotelians:

> Compare my assumptions with the assumptions of others. Compare all their *real qualities*, their *substantial forms*, their *elements* and countless other such things with my single assumption that all bodies are composed of parts. This is something which is visible to the naked eye in many cases and can be proved by countless reasons in others. All that I add to this is that the parts of certain kinds of bodies are of one shape rather than another. This in turn is easy to demonstrate to those who agree that bodies are composed of parts. Compare the deductions I have made from my assumption – about vision, salt, winds, clouds, snow, thunder, the rainbow, and so on – with what the others have derived from their assumptions on the same topics. I hope this will be enough to convince anyone unbiased that the effects which I explain have no other causes than the ones from which I have deduced them. Nonetheless, I intend to give a demonstration of it in another place. [2:200]

On some occasions Descartes does not explicitly reject the forms and qualities of Aristotelian physics but merely observes that they need not be "mentioned" in his physics (6:239, 3:492). Here, he takes his argument from comparative simplicity and unity of explanation to be sufficient to convince an unbiased mind that various natural phenomena "have no other causes" than particles of various shapes – that is, that they do *not* have as causes substantial forms and real qualities. Such an argument might not convince an Aristotelian who doubted whether Descartes' explanations really were more successful overall. Recognizing that the argument was not a strict demonstration, he continued to speak of a metaphysical demonstration, which became the *Meditations*.

## Foundations for physics

Another clue from 1638 can help us to see how Descartes thought contemplation of God and the soul could yield foundations for his physics, if we draw on Chapters 3–8. In letters to Mersenne and the Jesuit Vatier, he explained that he withheld the metaphysical demonstration from the *Discourse* because he didn't want to introduce radical skepticism into a popular work. Such skepticism was needed so that his readers might "withdraw the mind from the senses" (1:350–1, 560). From Chapter 7 we know that he put forth the pure intellect, devoid of sensory material, as the instrument for knowing not only the soul and God but also the essence of material things. He appealed to this same instrument to support his claim (Chapter 5) that God preserves matter in existence from moment to moment (according to the laws of motion).

On this interpretation, the metaphysical turn toward the pure intellect provided Descartes with a direct argument for core principles of his physics. Let us put this reading to work, considering first the foundations of Descartes' physics of the material world and then his physics of mind–body union and interaction.

### *Real qualities, extension as essence*

Descartes' denial of real qualities may not seem particularly radical now. Everyone who is acquainted with basic physics or introductory psychology knows the modern analysis of color perception, which explains color in objects using wavelengths of light (a distant relative of Descartes' spinning particles). But to Aristotelians and others in his audience, the denial of real qualities would have seemed particularly difficult to accept. Let us put ourselves in their shoes to see why.

Aristotelian real qualities are given that name because in an Aristotelian account the qualities we sense are direct representatives, or instances, of a quality in the object. When we see a red tulip, the real quality of redness is transmitted to our senses and received by our sensory soul as a "form without matter." The form of redness is what makes the tulip red; this same form is expressed in the red we experience, in accordance with Aristotle's principle that like knows like. In between, the form is transmitted "without matter" through the air, into the eye, and down the optic nerve (conceived as a hollow tube). This received form accounts for the phenomenal red we experience in perceiving the tulip.

The Aristotelian account has common-sense appeal because it says that our visual experience reveals the actual or "real" qualities of things. In some ways, however, the account as given by Aristotle was incomplete. Especially, the notion of a form without matter transmitted through a medium had to be filled out by medieval and early modern Aristotelians. If the form of red makes the object red, why doesn't it turn the intervening air red when transmitted through it? But the air between the tulip and us does not appear red; nor does the eye turn red when we see a red thing. To explain these facts, mainstream scholastic Aristotelians in the thirteenth to seventeenth centuries taught that the form in the medium has a special kind of diminished existence, called "intentional being," and so they termed the transmitted form itself an "intentional species." The technical term "intentional" conveyed two things: first, that the species of color "tends toward," "points to," or "represents" the color in the object; and, second, that the species of color in the air has diminished being, does not exist as a full-blown quality, and so does not turn the air red. In this way, they sought to square Aristotelian doctrine with the observed facts.

In the *Dioptrics*, Descartes proclaimed that he had no use for the "intentional species that exercise the imagination of the philosophers" (6:85*). In his account, everything in the sensory process (up to mind–body interaction) is purely mechanical. The quality of red in the object, the transmission of light and color, and the effect of light and color on the nervous system all reduce to the size, shape, and motion of particles. On this view (which is similar to Galileo's position), color in the object consists simply in the geometrical features of its surface, which cause it to put one or another spin on the spherical particles of light. This spin is transmitted to the eye, where it affects the retinal nerves in one way if the object is what we call "blue" and in another way if "red" (6:91–2). These differing effects in the nervous system and brain then cause differing sensations in the soul. Descartes did not deny that objects are colored; rather, he denied that color is a real quality of the sort envisioned by the Aristotelians. Color in objects is a purely mechanical property that affects the nervous system, causing a sensation of red. The experienced red – the content of the sensation – has an arbitrary but lawful relation (established by God or nature) with the brain that causes it, and hence with the physical property in objects (6:130–1, 7:81).

As Descartes saw things, he needed to overcome the natural human prejudice in favor of the Aristotelian resemblance thesis (as discussed in Chapters 5 and 8) in order to gain acceptance for his own theory. His initial reason for doubting that sensations of color and other qualities resemble something in objects was that they are "obscure and confused" (7:43, 80, 83). To see how this observation could challenge resemblance, we must ask: obscure and confused by comparison with what? If we simply consider the sensory experience, of a red ball, say, it hardly seems that our perception of the ball's redness is any more or less confused than our perception of its roundness. Both seem equally "in focus," phenomenally speaking. We must therefore seek another standard, by comparison with which our perception of the ball's color is obscure and confused, whereas perception of its shape is not.

Meditations 3–5 provide the needed standard. Descartes could argue that sensory ideas of color are obscure and confused by comparison with a clear and distinct (purely intellectual) perception of shape. In Meditation 3, he observes that color and other qualities are thought of "in a very confused and obscure way, to the extent that I do not know whether they are true or false, that is, whether the ideas I have of them are ideas of real things or of non-things" (7:43–4; see also 7:83). This experience contrasts with the intellectual perception of extension and its modes in Meditation 5, from which the meditator concludes that material things "are capable of existing, insofar as they are the subject matter of pure mathematics, since I perceive them clearly and distinctly" (7:71). Ostensibly, shape and other geometrical modes are clearly perceived to be potential properties of any possible material thing, whereas color is not.

An argument for excluding real qualities might then go as follows. Extension is the essence of matter. My sensory ideas of shape, size, position, and motion therefore present properties that things can have. I may sometimes be mistaken about the precise sizes and shapes of actually existing things, but the economy of the senses as bestowed by God ensures that I will be right some of the time. By contrast, I do not clearly and distinctly perceive color to be a possible property of objects. Ideas of color arise only from the senses, but I should rely only on my clear and distinct intellectual perceptions to tell me what properties things can have. My sensory ideas of color do not meet that standard. Hence bodies do not have the "real quality" color.

This argument draws on points from Meditations 3–6. But it has a serious flaw. It can be interpreted as an argument from ignorance. Perhaps color is a real quality, and the human intellect simply fails to perceive it to be one. We know Descartes was unwilling to assert that we know "all the properties" that are in mind or matter (7:220). Maybe we simply can't say whether color is a real quality or not.

This raises a question of interpretation. Does Descartes claim to perceive that color *is not* a possible mode of extension, or does he merely *not claim* to perceive that it is a mode of extension, as he perceives the geometrical modes to be? Does our intellectual perception exclude the real quality from matter, or is the status of color simply unknown?

It seems clear that Descartes actually wanted to exclude real qualities from bodies. But if his argument rests entirely on a direct intellectual perception that the real quality color is not a possible mode of extended substance, discussion ends there. The exclusion would rely on an intellectual perception of the nature of matter, pure and simple. This one-step argument offers little help if we don't immediately come to the same metaphysical insight ourselves. In Chapter 8, we found Descartes appealing to a principle that could shore up his argument – the "constitutive essence" principle, according to which all the modes of a substance must be "perceived through" its principal attribute. If we think of extension as the intelligible object of geometry (as we are instructed to do), then it has no color or other sensory properties. It has only extension, which can be divided into parts having size, shape, position, and motion (7:63–4, 73–4). If we subsequently try to think of color as a mode of extension, we find only obscurity and confusion. Indeed, Descartes claimed in the *Principles* that "we cannot find any intelligible resemblance between the color which we suppose to be in objects and that which we experience in our sensation" (8A:34).

In the argument for mind–body distinctness, Descartes parried the charge of arguing from ignorance by observing that he had clear and distinct perceptions that both mind and body can exist as complete things, on their own, without the other. In the present case, he could not argue that color is "really distinct" from body, for that would make color a substance – and he held that physical color in bodies arises from the size and shape (modes) of their surfaces, and that experienced color is a mode of mind (an idea or sensation). However, he might (and in fact did) argue that we can conceive of extended matter as existing without color, or the other so-called secondary qualities. In Part 2 of the *Principles*, Descartes repeated the point from Meditation 6 that the senses are not for showing us "what really exists in things" but for telling us what is beneficial or harmful to the mind–body complex (8A:41). To know what really exists in things, we must "lay aside the preconceived opinions acquired from the senses, and in this connection make use of the intellect alone, carefully attending to the ideas implanted in it by nature" (8A:42). He continued:

> If we do this, we shall perceive that the nature of matter, or body considered in general, consists not in its being something which is hard or heavy or colored, or which affects the senses in any way, but simply in its being something which is extended in length, breadth, and depth.

Considering the quality of hardness, he argued that if we never felt any bodies, hence never felt them as hard, they would not "thereby lose their bodily nature." He extended this thought experiment to the other merely sensory qualities:

> By the same reasoning it can be shown that weight, color, and all other such qualities that are perceived by the senses as being in corporeal matter, can be removed from it, while the matter itself remains intact; it thus follows that its nature does not depend on any of these qualities. [8A:42]

As in the argument for mind–body distinctness, Descartes here claims to perceive body as a complete being while explicitly denying it the perceived quality of color. It is not that he simply doesn't think about whether color is in body. He asserts that it is not. Hence, assuming he is thinking clearly and distinctly, he can claim to perceive that body, possessing essentially only the geometrical modes of extension, can exist as a complete being without color (as a real quality). But if matter can be a complete being without color, and if the properties that things have on their own must be instances of their essence, then here is an argument for excluding color. This argument is not explicit in the *Meditations* but may be latent in the perception of the essence of matter (Meditation 5) and the discussion of the respective roles of the senses and intellect in knowledge of bodies (Meditation 6).

Descartes drew other physical conclusions from the theory that extension is the essence of matter. Famously, he inferred that there can be no space distinct from matter, hence that a vacuum is impossible and the universe is a plenum (8A:49). There is no void, only matter in motion. Motion does considerable work in Descartes' physics. Let us therefore turn to the laws governing it.

### *Immutability, laws of motion*

In Descartes' metaphysical terminology, motion is a mode of extension. But extension, as the essence of matter, does not specify what laws, if any, motions follow, or even say what will happen when moving bodies collide. Two extended things cannot interpenetrate or coexist in the same place, so something must give when one body hits another. But the bare concept of extension offers no hint about the outcome. Descartes' concept of extended matter does not include the Newtonian notion of mass, with its implications for momentum and transfer of force upon impact.

Descartes conceived extended matter as intrinsically inert. It contains no activity, and it accrues no force in virtue of being in motion. Rather, all force and activity must be referred back to God, who preserves matter in existence from moment to moment, as in the Third Meditation.

The Third Meditation did not mention laws of motion, but it provided the foundation for such laws in God's preserving action. The laws themselves were set out in the *World* and *Principles*. God preserves the motions of bodies in accordance with laws governing their interactions upon impact (Descartes did not recognize laws for action at a distance). Both works portray the universe as possibly evolving out of a soup of particles, created by God with a certain quantity of motion (11:32–5, 8A:101; see also 6:42–4). This "quantity" is defined as the product of the speed of bodies and their volume of matter. (Descartes did not allow for matter of differing specific gravities; he explained the density in ordinary objects by hypothesizing that some are more porous than others.) He conceived of speed as a scalar quantity, which means that no change in the quantity of motion occurs when a body changes direction. He then sought to derive the laws of motion from God's immutability; in preserving the universe from moment to moment, he preserves the same quantity of motion as at creation.

Descartes purported to derive three laws from God's immutability. The first is "that each thing, as far as it is able, always continues in the same state; and so when it is once moved, it always continues on" (8A:62*). This law describes motion and rest as persisting states of things. The second is "that all motion, in and of itself, is along a straight line; therefore, those things that move in a circle always tend to move away from the center of the circle they are describing" (8A:63*). These two laws are similar to Newton's law of inertia (his first law of motion) but differ from it because Descartes did not treat motion as a vector quantity (which would mean that changes in direction alter the quantity of motion). The third law is "that one body, in colliding with a stronger body, loses none of its own motion; but in colliding with a weaker body, it loses as much of its motion as it transfers to that weaker body" (8A:65*). This law is implausible on the face of it, since it suggests that a snooker ball could never move the slightly larger balls used in pool, no matter how hard it was driven. Descartes tried to explain away such counter-examples by observing that in our matter-filled environment, the larger body is surrounded by the fluid of the air, allegedly making it easier to move (8A:70) – although presumably both bodies are surrounded in this way, so it is hard to see what differential effect there would be on their ease of motion.

Descartes offered as a ground for his first two laws "the immutability and simplicity of the operation by which God preserves motion in matter. For he always preserves the motion in the precise form in which it is occurring at the very moment when he preserves it, without taking any account of the motion which was occurring a little while earlier" (8A:63–4). The source of natural rectilinear motion is God's preserving power. This yields another difference between Descartes' law of rectilinear persistence and Newton's law of inertia. Newton's inertial law became explanatorily basic – a place where explanation stops. In Newtonian physics, the continued motion of bodies in a straight line no longer requires explanation, by contrast with the Aristotelian scheme, in which continuing motion requires a continuing cause. (Newton himself, at least for a time, regarded continuing motion as the product of an inertial force, but later Newtonians conceived of inertial motion as basic, without a continuing force.)

Descartes considered this picture, in which God preserves particles of matter from moment to moment according to their tendencies, to be certified by his metaphysics. Nonetheless, it has its problems. It may be objected that in a single instant a particle can have no tendency to move, since for Descartes (8A:53) motion is simply transference from one location to another (requiring finite time). The force of this objection depends partly on whether Descartes conceived of instants as merely vanishingly small or as dimensionless points. But it may also depend on whether God does book-keeping on the "tendencies" or directions of particles in motion. If God recreates the universe from point-instant to point-instant, then the notion of a continuous direction of motion would be entirely dependent on God's preserving action, not on any "tendency" internal to the moving body itself.

Another problem concerns the coherence of bodies. If bodies are composed of innumerable parts, how do these parts cohere to form a single unit? Apparently, he held that bodies form units because their parts are at rest in relation to one another (8A:71). In a moving body, the common motion of its particles would keep them together. The quantity of motion of a body is the product of the quantity of matter times speed. The quantity of matter is simply the volume of matter traveling together. Any impact between macro-level bodies involves the surface of one body, such as a cue ball, touching the surface of another body, such as the eight ball. The volume of the whole cue ball is used to determine how it will move the eight ball. But the balls are units only because their particles move together. As the lead particles make contact, their motion should be changed relative to the rest of the ball, breaking the unity. Why shouldn't a collision result in both balls dissolving into one another, like colliding puffs of cigar smoke? Perhaps because, as Descartes says, particles with irregular shapes catch on one another and hold together (8A:144). But how can infinitely divisible matter hold any shape at all? Presumably, because God so conserves it.

A further problem is that the three laws themselves do not define a determinate outcome for cases of impact. The third law says that one body loses as much quantity of motion as another gains. But it does not say how much each loses and gains. To address this question, Descartes provided seven rules of impact in the *Principles* (8A:67–70). Although these rules allegedly follow from the three laws, they are not strictly derivable. Moreover, as Leibniz later observed, when represented graphically they yield discontinuities when the sizes and speeds of bodies are only slightly altered. These problems led Malebranche, who generally tried to defend Descartes' physics, to admit the difficulty and reformulate the laws.

In practice, this last problem had little effect on Descartes' physics, for he did not refer to the rules of impact again in the *Principles*, and he only rarely mentioned the laws of motion themselves (8A:108, 117, 144, 170, 194). The explanatory work-horse in Descartes' physics was the mechanistic interaction of particles in accordance with their shapes and motions. This picture required that such interactions be governed in a regular way, a requirement addressed by the above laws. But in justifying various mechanistic models, Descartes appealed to analogies with ordinary cases of bodily interaction, not to precisely calculated exchanges of quantity of motion.

The significance of Descartes' laws of motion lies more in their overall conception than in any technical contribution to the analysis of impact. They offered the general vision of law-governed interactions of matter everywhere in the universe. The first and second laws described rectilinear motion as a natural state that does not diminish of itself and will continue for ever if unimpeded by other bodies. Although Galileo is sometimes credited with formulating a proto-version of Newtonian inertia, he in fact treated circular motion along the surface of the Earth as the "natural" state. He had no conception of straight-line inertia. Although Descartes' conception did not involve vector quantities, it was the historical precursor to Newton's law of inertial motion.

### *Matter, innate ideas, and eternal truths*

The essence of matter is extension, whose properties are understood through geometry. The ideas of geometrical essences inhere (innately) in the human intellect. Descartes asked some fundamental questions about these essences: why are they what they are? That is, why is the essence of the circle what it is, the essence of the triangle what it is, and so on? Furthermore, how does the mind come to have its innate ideas of those essences? The answers to these questions refer to the creative power of God.

As mentioned in previous chapters, Descartes held that the geometrical essences, as the essences of all created things, are free creations of God (1:145–6, 149–53, 7:380, 432, 435–6). God did not look to any standard or model, either independent of or internal to himself, in creating the essences; he simply made it the case that the radii of a circle are all equal to one another, and the angles of a triangle are equal to two right angles. He could have created other mathematical rules, so that the radii are not equal (1:152). Since our minds use the truths that actually were created, we may be unable to conceive such possibilities. (Descartes had no inkling of non-Euclidean geometry.) Nonetheless, he held, the mathematical essences (and others) are free creations of God's will.

The doctrine that the so-called eternal truths are God's free creations might seem to threaten human knowledge. What if God were to change them? On Descartes' view, nothing about the current set of essences required God to create them instead of others. If he reconsidered his act of creation, today's geometrical truth might be tomorrow's falsehood.

In fact, Descartes held that his doctrine provided a secure basis for human knowledge. On his theory, along with the eternal truths, God created the material world and various minds, with their respective essences, and he implanted innate knowledge of those essences in human intellects. God therefore adjusted the human intellect to the essence of matter (and, presumably, of mind). Moreover, since he is immutable, the threat of changing essences does not arise. Truths about essences remain "eternal truths" because once willed they are fixed for ever by God's immutability (1:149, 152).

In Descartes' context, this doctrine might actually have improved the theological palatability of his claim to know the first principles of physics. In the metaphysical theology of mainstream scholastic Aristotelians, knowledge of the essences of things implied an understanding of the absolute limits on God's creative power. These Aristotelians held that the essences of created things, such as a rabbit or an oak tree, depend on God for their existence. But that did not imply to them that God freely chose the essences things have. On their view, God could not create a rabbit that wasn't an animal, or that violated the essence of rabbithood in any other way. The essences are therefore eternal, because they are grounded in God's (eternally determined) creative power. God understands the essences by understanding what he can and cannot create. On this view, a natural philosopher claiming to know the essences of things – and especially claiming to know possible essences *a priori*, as did Descartes – would be claiming to have fundamental knowledge of God's power. Descartes' doctrine that the eternal truths are free creations permits the natural philosopher to claim such knowledge of essences without thereby claiming to comprehend the structure or limits of God's creative power. Since it was a tenet of Catholic theology that God cannot be fully comprehended, in this way Descartes could sidestep theological problems that might otherwise arise for his claim to understand "completely" what the essence of matter is. He could claim that the human mind's innate ideas are perfectly adjusted to the created world, not because the human mind is able to grasp the limits of God's power but because God has freely created the world with its essences and our minds with ideas of those essences.

## A mechanical philosophy

Descartes envisioned the world as a grand machine. This machine was not filled with cogs and gear-wheels but with fluids and pressures, spinning particles, and bits of irregularly shaped matter interacting to produce the phenomena of nature. In the *Meditations*, this mechanistic vision appears in the description of the human body as "a kind of machine equipped with and made of bones, nerves, muscles, veins, blood and skin" (7:84; also 7:229–30, 602). It was extensively developed in the *Principles* (as, too, in the posthumously published *World*).

The terms "mechanism" and "mechanical" have several meanings that might fit the concept of a mechanical philosophy. Beyond the comparison with a machine (discussed below), the terms may imply the blind following of laws without the intervention of undetermined will or choice. In this sense, even a dualistic psychology can be mechanistic if soul-substance is governed by laws. (Descartes proposed that the human will follows the rule of always choosing the apparent truth or apparent good, exercising the freedom of indifference only when the intellect fails to present clear truth or goodness [7:432–3].) In Descartes' physics, both material nature and mind–body interaction are governed by exceptionless regularities. His vision of nature was mechanistic in this first sense. But, unlike Newtonian physics, Descartes' natural philosophy is not filled with derivations from quantitative laws. His only published successes in fitting quantities to empirical phenomena were the sine law of refraction (6:101) and the work on the rainbow (6:336–43). We have seen that his theory of impact was generally a failure in fitting quantitative laws to observed phenomena.

Another aspect of a "mechanical" philosophy of nature is the banishment of active principles, vital forces, and action at a distance from natural processes. Descartes rejected the Aristotelian vegetative and sensitive souls and their relatives, which previously had been thought to govern (with a kind of implicit intelligence) the organic processes of living things. Whereas many previous natural philosophers, including the English theorist William Gilbert, as well as Kepler, accepted animistic theories of magnetic attraction, comparing the pull of iron to magnet to the attraction between lovers, Descartes offered his purely mechanical theory of subtle magnetic fluid (tiny spirals) interacting with threaded channels in magnetic bodies. The heat of fire was reduced to particles in motion, the action of light to pressure in an ætherial medium, and so on. There is no action at a distance; all material interaction is by direct contact.

"Mechanistic" can also mean non-purposeful, or without a guiding teleology. Descartes is famous for rejecting final causes from physics on the grounds that the human mind cannot hope to discern God's plan (5:185, 7:374–5, 8A:15–16, 80–1). (A "final cause" is the purpose for which something comes into being or changes state.) The explicit target of this rejection is the view that all of nature has been organized for the benefit of humankind. Descartes' cosmos was populated by many suns with many planets; he felt it ludicrous for human beings to suppose that the Sun and stars were created expressly for their benefit (3:431). He also banished final causes from the laws of motion. Aristotelians thought that earthy matter moves toward the center of the universe as its end or final cause (although without attributing awareness or knowledge to it, contrary to Descartes' caricature [7:442]). Descartes admitted no such "ends" into material interactions or bodily motions.

However, Descartes did not banish all teleological thinking from natural philosophy. In describing the composite human being (mind and body), he spoke of God or nature having arranged the rules of mind–body interaction so that sensations tend toward the preservation of the composite being (hence toward the health of the body [7:80, 87]). This counts as invoking purpose, teleology, or final causes in analyzing the mind–body relation and the functioning of the senses. Similar teleology appears in his physiology, where he spoke of the "functions" of the parts of the body, or what they "serve" to do (7:374–5; 11:121, 154, 224).

A final sense of "mechanical" means machine-like, or pertaining to machines. The most basic notion of machine in Descartes' time derived from the ancient science of mechanics, in which the lever was regarded as a simple machine. Descartes invoked this notion in proudly proclaiming of his philosophy that, "like mechanics, it considers shapes and sizes and motions" (1:420), and he composed a brief treatise on mechanics (1:435–47). But his philosophy was mechanical in a broader sense, in that he compared natural phenomena and animal bodies to complex machines with interacting parts. Many of Descartes' mechanical explanations take the form of analogies with effects observed in ordinary experience (8A:324–6). They use analogies to characterize micromechanisms, which in turn (purport to) explain the known phenomena of nature. Descartes explained the properties of water by comparing its particles to eels, the viscosity of oil by comparing its particles to branchy bushes that can stick together, like tumbleweeds (1:423), and magnetism through screw-shaped effluvia and threaded channels (8A:275). His grandest comparison was between the human body and the hydraulically driven automata found in the royal gardens of Europe in his day (11:130–1). This comparison again evokes latent teleology, regarding the design or function of the parts of the machine.

## Mechanized body, embodied mind

Descartes' mechanical philosophy rejected animism everywhere, save for the human body (joined with a mind or soul), and perhaps the world as a whole (where quantity of motion is preserved by God). From the perspective of twentieth-century naturalism, this seemed like two animisms too many. In that century, Descartes was accused of putting a "ghost in the machine" of the human body.

Emphasis on Descartes' dualism can mask the extent to which he promoted a naturalistic, anti-vitalistic materialism concerning living things. Aristotelians and other vitalists were "naturalists" about living things inasmuch as they considered plants and animals to be part of nature, and hence their powers and active principles to be natural. By the standards of twentieth-century materialistic naturalism, however, their list of natural powers was too liberal. On those standards, the vegetative and sensitive powers of the Aristotelians, as also Descartes' immaterial mind, were non-naturalistic. Despite its dualism, Descartes' philosophy promoted a materialistic naturalism toward living things by holding that plants, animals, and the human body are nothing but machines. Indeed, he extended that sort of naturalism to animal psychology generally and to much of human psychology, which he thought could be explained through bodily mechanisms alone, independent of mind.

### *Machine men*

The most complete description of Descartes' mechanistic physiology is the *Treatise on Man*, although portions were discussed in the *Discourse*, *Dioptrics*, *Meditations*, *Principles*, and *Passions*. The basic vision is simple – human and animal bodies are machines that respond to their environments through sensory stimulation, seek food when they haven't eaten, form material memories, and learn in response to sensory stimulation. As he wrote in Meditation 6, one may consider the human body "as a kind of machine equipped with and made up of bones, nerves, muscles, veins, blood and skin in such a way that, even if there were no mind in it, it would still perform all the same movements as it now does in those cases where movement is not under control of the will or, consequently, of the mind" (7:84). Moreover, since he denied minds to animals, all of their behavior had to be accounted for mechanistically. Much of human behavior (all responses not affected by will, or requiring general intelligence) could, he thought, be explained in the same way (see also 6:56–9).

Descartes thought of human and animal bodies as powered by a "fire without light" that burns in the heart (11:202, 333). This fire heats and expands blood as it enters the heart, acting like a boiler in a steam engine. The blood exits the heart moving quickly, some proceeding to the brain. There, at the base of the brain, the "animal spirits" – the subtler and livelier parts of the blood – are filtered out and enter the central cavity of the brain through the pineal gland. Some of the spirits then proceed down the nerves (conceived as hollow tubes) to the muscles; on entering a muscle they cause it to inflate like a balloon, become taut, and contract. Muscle movement and hence behavior are determined by which tubules the spirits enter (11:129–43, 170–97).

A sensory-motor loop controls the dispersal of the spirits. Sensory nerves are filaments encased in the tubules. When a sense organ is stimulated, the filament jiggles in a certain way, which causes it to tug