

Cartesian Science

(*Discourse V* [AT VI: 40-45]; *Principles of Philosophy* II.4-23, 36-40, 64; IV.198-99, 203-4 [Matthews 99-108]; *Discourse VI* [AT VI: 63-65])

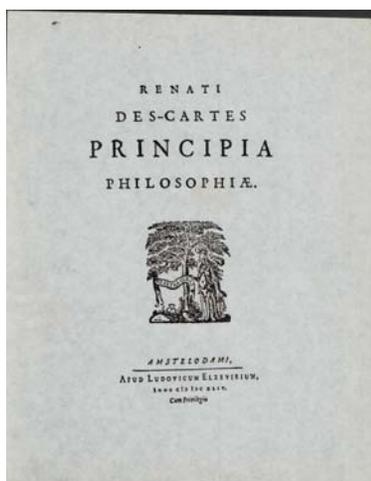
QUESTIONS ON THE READING

1. Are there any random or chance occurrences in nature, according to Descartes? (This question and the following two are on *Discourse V*.)
2. In giving his account of the nature of matter in *Discourse V*, what features or properties did Descartes explicitly identify as ones he had no use for and did not need to suppose matter to have?
3. How did Descartes respond to the objection that it is contrary to the creation story of the Bible to suppose, as he did, that all God needed to do to make the solar system, the Earth, the arrangement of water and minerals on the Earth, the weather, and the life on Earth, was institute certain laws and set an originally chaotic arrangement of matter in motion?
4. What is hardness, as far as our senses are concerned? (This question is on the online reading, questions 5-10 are on the selections from Matthews.)
5. Why must the quantity of motion in the universe be preserved?
6. Is it natural for bodies that have been set in motion to slow down and stop? What is it that teaches us the answer to this, sense experience or understanding?
7. What do the nerves transmit to the brain?
8. Where does the feeling of titillation or pain, and the appearance of light and sounds originate?
9. What makes it unlikely that the colours we sense are produced by colours actually existing on the surfaces of bodies?
10. What is the major guide Descartes relied upon when deciding what hypotheses to formulate about the workings of the small parts of nature?
11. Is there a role for experimentation in Cartesian science, and if so what is it? (This question is on the selection from *Discourse VI*.)

NOTES ON THE READING

Cartesian science is built on the foundations Descartes had established by the close of *Meditations VI*: A certainty that extended things exist, an optimism about the possibility of uncovering the truth about exactly how the extension of particular things is modified through a careful use of the senses and reason, and a doubt about whether these things have any other properties than those arising in them as a result of the way their extension is modified. As noted in the previous chapter, far from viewing this remaining doubt as an impediment, Descartes seized upon it as an excuse for initiating a rigorously mechanistic program in physics. He cleverly saw that he did not need to actually deny that bodies have qualities like those depicted in our ideas of colour, smell, taste, and heat and cold — a denial that would only have precipitated needless theological controversy over his position on the Eucharist. He only

needed to go ahead and do a physics that made no reference to sensible qualities, showing, by the



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ease with which he was able to account for all the phenomena of nature, that these qualities have no role to play in our account of the workings of the world. Even if they do exist, they do not do anything.

In *Discourse V*, Descartes claimed to have achieved this goal and accounted for all the phenomena of nature without having to suppose that bodies possess any of the sensible qualities. Indeed, he carried this project a step further and claimed that physics could not only do without sensible qualities like colour, scent, and temperature, but also without dispositional properties like weight, solidity, hardness, and charge. All that bodies need to possess, he claimed, is extension and those modifications that follow from extension: shape, size, position, order, and motion. In effect, bodies need be nothing more than spaces that can be transported from one place to another. These spaces need not be solid, impenetrable, or heavy, nor need they vary in mass or density. All materials are composed of the same fundamental element, extension, cut up and arranged and moving in various ways. Yet this ontology, bare as it is, was all Descartes thought he needed in order to account for the stars and planets, the various elements and minerals on Earth, light, fire, gravitation, magnetism, and even living bodies.

In explaining how all of these different things could emerge as modifications of cut up pieces of bare extension, Descartes relied on three fundamental principles: the denial of the existence of a vacuum, the doctrine of constant creation, and a claim that God is supremely constant in all of his operations.

The first of these principles, the denial of the existence of an empty space or vacuum, is one that Descartes argued for over *Principles* II.17-18. A special argument is necessary because, even though Descartes thought that bodies are nothing more than cut up bits of space, it does not follow from this that wherever there is space there is body. A body is a *movable* space, and it is a serious question whether there might not also be an immovable space (often called “place”) that stays where it is and so remains behind when a body moves away from it. We do think this way about places. We think that they stay where they are, and we think that there is a kind of space that consists, not of the extension of some movable body, but of the aggregate of places — a kind of infinite or indeterminately large container. Descartes was concerned to argue that this latter notion is absurd. If we only pay attention to what we very clearly and distinctly perceive in our idea of an empty space, he claimed, we will see that the idea of an empty space is the idea of a space that contains nothing, not even air or light or magnetic effluvia (naturally, Descartes supposed that magnetism is the product of a stream of particles rather than a force field). But if an empty space contains nothing, then to say that a certain space, say the space between the walls of a vessel, is empty is to say that there is nothing between the walls of the vessel. But if there is nothing between the walls of the vessel, then they must be together. In other words, it is not merely physically, but logically impossible that empty space or nothingness should exist.

Our views to the contrary are, Descartes claimed, due to the fact that when we see a body move relative to certain landmarks, we are still able to specify the original place of the body by reference to the landmarks. This makes us fall into the error of thinking that the place exists independently of the body that was in it. What really happened was that the body moved away, carrying its space with it, and was replaced by some other body, carrying its own extension. But, because the replacement occupies the same position relative to the landmarks, we think of it as being in the same place and imagine that the place exists independently of either body. Then we concoct the idea of immovable space as the aggregate of places. But in fact place is not a real thing, but a mere relation. Were there no landmarks relative to which places could be defined, there would be no



places — it is not just that we would not be able to identify places; they would not exist because they have being only in relation to landmarks.

Descartes took the fact that there is no empty space to entail that all motion must be the rotary in nature. After all, if the world is full of body, then the only way anything can move is if a whole ring or sphere or cylinder or other cyclical form rotates. This in turn entails that matter would have to be infinitely divisible. In a universe composed of a solid mass of cubes, motion can occur as long as the cubes slide past one another in a line. But if the cubes must move in a curve, they could not pass one another without creating gaps, that is, empty spaces. Since that is impossible, the pieces of extension must constantly be bending and breaking as they move past one another, in order to generate little pieces to fill the interstices that would otherwise form, and these pieces must be arbitrarily small. (*Principles* II.20 offers a different, less self-serving reason for believing that bodies must be infinitely divisible: Since any body must be extended, and what is extended has sides set outside of one another, it must be at least possible for God to separate one side from the other.)

This gives rise to one of the characteristic features of Cartesian physics: its preference for explaining natural phenomena by appeal to vortices of aetherial matter. A casual survey of the later parts of Descartes's *Principles* reveals page after page of diagrams of vortices. Descartes appealed to vortex mechanics to explain the motions of the planets (the planets are supposed to be carried around the sun by vortices), the causes of the tides (a vortex swirling around the Earth is supposed to get compressed under the moon, so that it presses on the ocean and causes a bump to rise in the water), the gravitation of falling bodies, the prevailing winds, the emission of light, the causes of fire, magnetism and static electricity, sunspots and earthquakes, and so on. Descartes's account of the motions of the planets is particularly worth remarking upon. Galileo had been condemned by the inquisition for holding that the Earth moves around the Sun, and Descartes was accordingly careful to insist that his own theory was consistent with church dogma in holding the earth to be at rest. The Earth is at rest, Descartes said, because it is at rest in its vortex — but then he went on to add that the vortex just happens to be revolving around the sun — a piece of reasoning that, in his own estimation, allowed him to “deny the motion of the Earth more carefully than Copernicus and more correctly than Tycho” (*Principles* III 19).

Consistently with his rejection of vacuum, Descartes also claimed that rarefaction and condensation (expansion and contraction) must be due to the entry or exit of foreign bodies into inflatable and compressible chambers within the circumference of a body, and that it must only be possible to compress bodies down so far (to the point where all the foreign matter has been squeezed out of their chambers and their walls are completely collapsed. Differences in the mass and density of different materials, like equal volumes of lead and wood are not due to the fact that these bodies have a property called weight, but are rather due to the fact that they are more or less porous. Wood has large pores through which more subtle matter readily flows and when we go to move it, it looks like we are moving a solid volume, but really we doing the equivalent of moving a sieve through the air. There is really not that much material there to move. Lead has smaller pores and that is why it is harder to move. There is actually more of it in the space, and more effort is required to set all of that material in motion.

The second principle that Descartes appealed to is the principle that God is supremely constant in all of his operations. Descartes took this to follow from the perfection of the Divine nature. An all-perfect being would not change his mind, since that would show indecision, uncertainty, or lack of foresight. Accordingly, God always operates in the same way.



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This second principle needs to be combined with a third one, already established in *Meditations* III: the doctrine of constant creation. Recall that according to that doctrine God must constantly recreate the world from one moment of time to the next. Since it is of the nature of time that the past no longer exists, a bare tick of the clock, meaning that the present moment has become past, signifies that everything that now exists has been annihilated as a necessary result of the passage of time. It must, therefore, be recreated in order to be sustained in existence. God is constantly doing this. This is the doctrine of constant creation. But now we need to think that God is supremely constant in all his operations. Combining these two doctrines yields the result that in recreating the world from one moment to the next, God will conserve everything, recreating each body that existed at the previous moment and putting into it just those modifications it possessed at the previous moment. Among these modifications would be a state of motion, and Descartes thought that having once injected a certain quantity of motion into a body God would recreate that motion from moment to moment in an unchanging way, just as he would recreate the body itself. This means conserving both the direction and the speed of the motion and so recreating the body just slightly further down on a straight line path. The effect of this operation is to underwrite what was later called the principle of inertia: the principle that each body in the universe, once set in motion, will continue in that motion in the same direction and at the same speed, unless something special happens to alter that state.

Descartes recognized one such special cause of a change of motion: collision. From time to time, as a body moves, it will run into other bodies standing in its path. (Indeed, in a plenum, that is, a world that contains no void, this will happen in no time at all.) When running into an impediment, the body cannot simply pass through, since we very clearly and distinctly perceive that two different bodies cannot occupy the same place at the same time. Consequently it must either drive the impediment on in front of it, or bounce back, or come to rest and transfer its motion to the impediment (or, more precisely God must so recreate it), and whichever of these cases occurs, the overall quantity of motion cannot be increased or diminished. Just which of these three cases occurs in which circumstances is something Descartes thought he could deduce from the constancy of the Divine operations, but that is a detail that we need not consider here. Those who are curious may consult what he has to say in *Principles* II.40-52. The main point to appreciate for purposes here is just that, on this scheme, the motions of the parts of matter are rigorously determined by the laws of inertia and collision. The one exception to these rules concerns the motions of those bodies that finite minds are substantially united to (i.e., human bodies). God is willing to move these bodies in ways projected by the wills of the minds that they are attached to.

On the basis of nothing more than this simple physics, Descartes proposed to explain the evolution of the solar system from an original, chaotic state, the formation and burning of the sun, the formation of the planets and evolution of the various minerals on earth, and even the evolution of life and such physiological processes as the beating of the heart and the circulation of the blood. All of these phenomena, he claimed, originate from nothing more than the motion and collision of otherwise uniform and undifferentiated particles of matter. There is no need to invoke forces of impenetrability, chemical bonding, electromagnetic or gravitational attraction, radioactive decay, or notions of variations in mass, and certainly no need to ascribe different sensible qualities to bodies.

Here is how Descartes attempted to justify his position.

He supposed that the universe consists of three different kinds of matter: gross matter (which goes to make up very large bodies like the planets and the bodies on the planets like our own bodies, the water, and the air), intermediate matter (which goes to make up the aether in the



heavens), and subtle matter (which goes to make up things like light). Intermediate matter is composed of very tiny, approximately spherical bodies, and is the original form of matter. Subtle matter is created when the pieces of intermediate matter move and some of them break into extremely tiny, spiky pieces that fill in the interstices that would otherwise form between the subtle matter. Gross matter is composed of pieces of subtle matter that get stuck together to form jagged, twisted shapes that readily interlock with one another to form arbitrarily large chunks.

Originally, when God created the universe he just created intermediate matter in a very compact form (squashed into cubes, as it were). But then God injected a certain quantity of motion into the universe, and, being supremely constant in his operations, preserves this same quantity of motion through the rest of time. The moving pieces of intermediate matter quickly generate subtle matter, which generates stars and suns, which in turn generate gross matter, which generates the planets and the minerals, vegetables and animals on the Earth. As noted earlier, vortex mechanics is supposed to take care of all the details.

While Descartes paid lip service to the Christian dogma that God spent six days creating the world out of nothing and ordering all its parts, he also observed that God could have simply injected a certain quantity of motion into a chaotically arranged mass of particles. Simply as a result of the necessities of vortex mechanics, systems of stars and planets, and worlds like our own would very quickly evolve. Be this as it may, he added that the doctrine of constant creation makes it sufficiently evident that God is required to sustain the universe from moment to moment, and indeed, make the laws of physics possible. So we need not worry that casting doubt on the creation story will in any way damage the need to accept the existence of God.

One final feature of Descartes's physics deserves some consideration: its position on the role of experiment and hypothesis. As so far described, Descartes's science proceeded in what might be described as an exclusively top-down fashion. From metaphysical first principles concerning the nature of God and matter, Descartes proceeded to derive the laws of motion, to deduce the necessity of the existence of vortices and the three main kinds of matter, and to account for the origin of the general kinds of things: the Sun, planets, minerals, winds, tides, and so on.



Descartes's Scientific Method

Metaphysical First Principles



Laws of Nature



← Gap

Specific Laws ← Hypotheses



Sensory Experience

But Descartes noted that this exclusively top-down procedure could not suffice to explain the nature and operations of more particular objects, like the particular species of animal and vegetable life. The reason for this is that the first principles and what follows from them are too simple and general. They tell us that everything that happens must be the result of rolling vortices and the impact of particles. But what vortices and particles, moving in what ways? Just as it is possible to compose an infinite variety of novels with the few letters of the alphabet, so it is possible to account for the generation of an infinite variety of different species of things from the mechanical principles. To discover what species actually exist, as opposed to what ones might possibly exist, we appear to need recourse to experience.

But this is just one respect in which it appears we must have recourse to experience. When we attempt to explain why particular species behave as they do, we find ourselves not so much as at a loss for an explanation as overwhelmed with the number of different possible explanations. Just as it is possible to make clocks with many different arrangements of gears and wheels that will all tell the same time, so it often appears possible to conceive of many different mechanical devices that could all just as well produce the same visible effect. Sunlight melts wax but hardens clay. How are we to account for this? Shall we say that the clay is composed of particles of sticky, gross matter between which particles of round, aetherial matter have been trapped, so that the round particles grease the sticky ones and make the clay malleable, but that the particles of sunlight knock



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the watery particles out, so that the remaining particles of gross matter cohere strongly? Shall we say that the wax contains gross matter and that the sunlight exercises a pulverizing action that has the effect of turning the wax fluid? These explanations would work, but we can readily conceive of a number of different “machines” that could produce the same visible effect. Perhaps the sunlight causes the clay particles to merely vibrate and rearrange themselves in such a way as to enclose the water particles in chambers, rather than knock the water particles out. Perhaps the wax particles are of a type that can slide past one another when they are set into vibration by incoming fire particles, but that, when moving slowly, readily get caught and hooked into one another. Since we do not have microscopical eyes we have no way of seeing the fine, corpuscular structure of these different materials in order to determine exactly what machine makes them behave as they do. How, therefore are we to proceed?

Under these circumstances, Descartes thought that we have no recourse but to consult our experience with the operations of the larger-scale objects whose parts we very readily can see, particularly the machines of our own invention. To understand the operation of the muscles for instance, we must consider how we would construct devices to alternatively draw strings together and release them. We must then provisionally suppose that some such machine is the one that actually produces muscular motion. That is, we must formulate a hypothesis. And then, if there are rival, alternative hypotheses that both seem to be likely ways of explaining the phenomenon, we must look for some respect in which they are different and devise some sort of experiment that, when performed, would yield one type of result when one machine is responsible, but another if a different one is responsible. We must then choose in favour of that machine that our experience of the results of the experiment indicates. For example, in the case of the two rival explanations for why it is that the Sun melts wax mentioned earlier, we could consider that if the first explanation is correct, then the wax ought to remain fluid when it is removed from the sunlight, whereas if the second is correct the wax should quickly solidify again. We could perform the experiment of removing the wax from the sunlight to determine which in fact occurs, and then accept or reject the indicated hypothesis.

Of course, our hypotheses cannot be wild: they have to conform to the things Descartes claims to have established so far. They cannot involve postulating unextended bodies, forces, real qualities, or other non-mechanical modes of explanation, and they cannot violate the laws of motion or collision. But within these broad bounds, we are free to speculate about precisely what mechanism may be producing the phenomena we observe.

Cartesian science may accordingly be viewed as a three-tiered structure. On the top tier is metaphysics and first philosophy and all of the things we clearly and distinctly perceive. It is there that we do the exercise of the Meditations and establish the fundamental principles of physics. It is there that we learn of the existence of God, of the equation of body and extension, and of the laws of motion and collision.

On the bottom tier is sensory experience. It is there that we learn, more or less accurately, what particular sorts of objects there are in the regions immediately around us and what sorts of effects these objects have on us. It is experience that teaches us such things as that there are planets that are carried in circles through the constellations, that there are tides, that iron is attracted towards the magnet, and that bodies that feel heavy in our hands tend towards the centre of the earth.

In between the top tier and the bottom there is a gap. Descartes recognized that science cannot proceed in a purely top-down fashion to derive all the particular features of the world from general



principles. From first principles we can only carry our deductions so far, to draw conclusions about general laws and structures. After that, we must go down to the sensory level, accept what it tells us about what the particular phenomena of nature are, and construct hypotheses that connect the general principles found at the top level with the phenomena observed at the sensory level. These hypotheses must be consistent with the general principles and of such a nature as to allow us to see how the specific phenomena follow. But because there will typically be alternative, rival hypotheses, all apparently capable of connecting the general principles with the observed phenomena, we cannot simply accept the hypotheses as statements of the truth of the matter. We instead have to rely on sensory experience of the results of crucial experiments to help at least narrow down the range of alternative hypotheses.

The middle tier of Descartes's system, the tier where the gap in the deduction occurs and at which hypotheses are made, is therefore simultaneously determined by both the lower and the upper tiers. The hypotheses that are arrived at must be consistent with the principles discovered at the upper tier, but it is the lower tier that tells us what these hypotheses have to explain, and it is the lower tier that judges their adequacy.

In this way, we might hope to eventually arrive at the correct hypothesis. But in the meantime we must, as Descartes put it in the closing sentence of the *Meditations*, "acknowledge the infirmity of our nature."

ESSAY QUESTIONS AND RESEARCH PROJECTS

1. Descartes's position that there is no such thing as space, but just extended bodies in a plenum, was challenged in his own day by Pierre Gassendi, and in the generation after by Isaac Newton. Both Gassendi and Newton maintained that space is something in its own right, that would continue to exist even if bodies were annihilated, and Newton maintained that an "absolute space" (a space that is not defined relative to bodies but is supposed to be separate from them and immovable) must be presupposed as an ultimate reference frame for inertial motion. Newton's claims that space is absolute and independent of bodies were later attacked by Gottfried Leibniz and defended by Samuel Clarke, in a correspondence that was widely published at the time and continues to be reprinted. Write an essay on one or more of the following: Gassendi's reasons for rejecting Descartes's position, Newton's reasons for rejecting Descartes's position, Leibniz's reasons for rejecting Newton's position, Leibniz's own position on space, Clarke's reasons for rejecting Leibniz's position. In each case assess the adequacy of the reasons presented *vis à vis* the adequacy of the reasons for the rival position. Gassendi's views can be found in Craig B. Brush, ed., *The selected works of Pierre Gassendi* (New York: Johnson Reprint Corp., 1972), pp.383-390. Newton's can be found in the selection from the Scholium on absolute space and time in Matthews. Leibniz's correspondence with Clarke is available in multiple, separate volumes and in various collections of Leibniz's works.
2. Descartes's position that the essence of body consists just of extension, so that whatever other real qualities a body might in fact have are ones that would have to be merely accidental to it and that it could stand to lose without ceasing to be a body, was in perfect accord with the mechanistic outlook of the early seventeenth century, but it was challenged in the later part of the century. Locke maintained, in opposition to Descartes, that bodies must have a real quality of solidity in addition to extension. Newton maintained that all the bodies we know of are impenetrable and have mass. And Leibniz argued that bodies must be conceived as



centers of force. One force that Leibniz attributed to bodies is a repulsive force, responsible for impenetrability and the communication of motion upon collision. Leibniz briefly explained why this force must be supposed essential to bodies in Part II, Article 4 of his “Critical Remarks [or ‘Critical Animadversions,’ as it is sometimes translated] on the General Part of the Principles of Descartes” (available in various edited translations of Leibniz’s works), as well as in a paper, “Whether the Essence of a Body consists in Extension,” published in the *Journal des savans* of June 18, 1691 and available in translation in Philip P. Weiner’s collection (*Leibniz. selections*. New York: Scribner, 1951). Recount Leibniz’s argument against Descartes and assess its adequacy.

3. Leibniz’s view that repulsive force is responsible for the transmission of motion upon impact naturally led him to suppose that collisions would always have to be elastic. This in turn led him to attack Descartes’s account of the laws of collision on the ground that they violate a fundamental metaphysical principle, the law of continuity. Outline Descartes’s account of the laws of collision as stated over Part II, Articles 46-53 of his *Principles of philosophy* and Leibniz’s critique, given over Part II, Articles 46-53 of his “Critical remarks on Descartes’s principles.”
4. In Part II, Article 36 of his *Principles of philosophy* Descartes maintained that the same quantity of motion is present after collision as before, so that quantity of motion is conserved through collision. Leibniz objected to this view, maintaining that it is rather the quantity of moving force in bodies that is conserved through collision. (The moving force or “*vis viva*” is another of the forces Leibniz attributed to bodies.) Descartes considered the quantity of motion to be the product of the quantity of matter and its speed, a formula very close to that Newton was to propose when he maintained that momentum or the product of the mass of the moving bodies and their velocities is conserved through collision. Leibniz, in contrast, maintained that what is conserved is not the product of mass and velocity, but the product of mass and the square of velocity. This led to a protracted controversy, the so-called *vis viva* controversy, that divided Leibnizian and Newtonian physicists over the better part of the 18th century. Leibniz’s original reasons for rejecting the Cartesian view are found in many places: in Part II, Article 36 of his “Critical comments on Descartes’s principles,” in article 17 of his *Discourse on metaphysics*, and in a paper entitled, “A Brief Demonstration of a Notable Error of Descartes and Others concerning a Natural Law,” published in the *Acta eruditorum* of March 1686 and widely available in collections of Leibniz’s works. Recount Leibniz’s reasons for disagreeing with Descartes.

