Descartes' *Principia*: the Vortex Theory of the Heavens

I. The Cartesian "Shift" of Emphasis in Science

A. Understanding as One of the Goals of Science

1. Part II of Descartes' *Principia* contrasts sharply with such works as Kepler's *Epitome* and Galileo's *Two New Sciences*, suggesting a very different view about what is important in science
    a. In particular, Descartes seems on the surface to be emphasizing a goal of explanation and understanding to a greater extent than they did
    b. I.e. explanation in terms of the fundamental or ultimate workings of the material world
2. Descartes was scarcely responsible for the idea that one of the goals of empirical inquiry is to provide an understanding of the world around us
    a. Ptolemaic astronomy was surely trying to explain -- i.e. provide an understanding of -- such phenomena as retrograde motion and patterns of variation in it
    b. And many of the Medieval and Copernican critiques of such aspects of Ptolemaic astronomy as the equant were tantamount to denying that he was providing such an understanding
3. As Ptolemaic astronomy and Aristotelian physics attest, however, one can achieve what at the time seemed a satisfactory level of understanding, yet subsequently conclude it was all illusory
    a. The issue is not just whether a particular line of explanation yields satisfactory understanding, but further whether it is true, so that the understanding is not an illusion
    b. For example, the line of explanation and the understanding it provides should stand up over time, as we learn more in the way that the telescope led us to
4. If Descartes and the other advocates of the mechanical philosophy added anything here, it was through their insistence on no compromises in explanation
    a. They were as willing as anyone to allow the positing of unseen theoretical entities in order to explain phenomena
    b. But, in insisting that we must be able to understand exactly how such entities work, they were placing a new burden on theorizing
5. By contrast, Kepler and Galileo were prepared to leave such detailed workings open so long as they had other grounds for pursuing their theories
    a. For example, Kepler allowed questions about how magnetism works to remain open, thinking that the promissory note can ultimately be redeemed since magnetism a natural phenomenon
    b. And Galileo allowed questions about why things accelerate vertically to be put off entirely

B. The Focus on the Foundations of Science

1. The most glaring shift in emphasis we see in Part II of the *Principia* is the concern with the ultimate foundations of all material processes
    a. From the title of Part II on, Descartes is engaged in a project of a completely different sort from Kepler and Galileo

b. Endeavoring to lay the foundations for all empirical knowledge!

2. One way of motivating his preoccupation with foundations is as a response to the pseudo-explanations of Aristotelian science and Renaissance naturalism
   a. Need to maintain sharp contrast between theorizing that yields a real understanding of why phenomena are the way they are and schemes that allow us to talk of phenomena coherently and without obtrusive anomalies
   b. To the extent that can identify all -- or at least some -- of the basic mechanisms of the material world, in a position to draw this contrast and then at least to recognize when all we have is a comfortable way of describing phenomena
3. Another way of putting this is that we want to be clear about what questions we are asking about the material world, and what we are demanding in the way of answers to those questions
   a. In particular, which why-questions call for answers other than, "that's just the way things are", and what sorts of answers to these questions we want -- e.g. answers that do not give rise to a multiplicity of further why-questions
   b. Descartes here following the lead of Aristotle, but in setting forth the fundamental principles of the material world, trying to minimize the number of why-questions to which the answer, "that's just the way things are", is appropriate
4. This focus on questions -- especially on why-questions -- is tantamount to trying to make explicit and clear what has subsequently become known as the conceptual (or metaphysical) foundations of science
   a. Not an irrelevant or premature undertaking, for the way we conceptualize phenomena is surely going to have an impact on any empirical theories we advance about them
   b. E.g. Kepler conceptualized motion as requiring a continuing push, Galileo conceptualized rolling as fully akin to falling, and Copernicus conceptualized uniform circular motion as calling for no further explanation
5. As we shall see, regardless of whether Descartes thought he was setting out the ultimate mechanisms of the material world or just making his way of conceptualizing motion and its change clear, his new focus on foundations had quite an effect
   a. Not just Newton, but virtually all others working in mechanics for the next 150 years extremely careful to lay out foundations -- often in prima facie conflict with one another
   b. Contrast this with work on mechanics before Galileo -- e.g. by the Italian and Dutch -- and even to Galileo, who focused on axioms -- mathematical foundations -- not on conceptual or explanatory foundations

C. Comprehensive Versus Piecemeal Science

1. The other dramatic shift in emphasis we find with Descartes is the demand for a comprehensive explanation of all phenomena

a. Or, judging from the qualification Descartes offers at the end of the *Principia* (IV, 206), at least the broad outlines of such a comprehensive explanation
b. In a way this is what is primarily responsible for his *Principia* seeming so different from the other things we have read from the first half of the 17th century

2. Both Kepler and Galileo were entirely comfortable with engaging in piecemeal science -- i.e. cutting off some comparatively distinct domain of phenomena and constructing theories about it
   a. Kepler: planetary motion, ignoring such things as cometary motion, novas etc., with no explicit defense that this domain is thus isolable
   b. Galileo: even more restrictive theoretical domains, idealizing away from nature, but with an explicit defense that empirical theory will not be forthcoming otherwise
3. Descartes, by contrast, shows a deep distrust of such piecemeal approaches to science not just in *Le Monde* and the *Principia*, but also in his critical comments about others -- e.g. Galileo
   a. "Top down science" insofar as at least the broad outlines of an overall comprehensive theory need to be in place before turning to such limited phenomena as magnetism
   b. Descartes' reason clear: thinks theorizing about limited phenomena inadequately constrained otherwise, and hence cannot be successful
4. The common response to this aspect of Descartes -- e.g. by Drake in his response to Descartes' critique of Galileo -- is simply to say that he was a philosopher and not an empirical scientist
   a. That is, Descartes' insistence on comprehensive instead of piecemeal science was nothing but an unfortunate vestige of his scholastic education and of his view that the goal is to replace the Aristotelian scheme with a new such scheme
   b. The trouble with this response is that it brushes aside all questions about whether there is any sort of valid scientific reason to adopt such a top down approach
5. This raises the question, did Descartes have any strictly "scientific" reasons for objecting to piece-meal science and insisting on a more comprehensive approach
   a. For example, could he have argued that only in this way will high quality empirical evidence be possible
   b. Given the struggles with evidence at the time, not a wild idea
   c. We have added reasons for raising this question and keeping it in mind as we proceed, for questions about top-down versus bottom-up science persist today in many fields

D. The Legacy of Descartes' Mechanics
1. The mechanics Descartes laid out in Part II of his *Principia* left a notable legacy
   a. I.e. ideas, principles, and approaches that became central to 18th century mechanics -- what we now call "Newtonian mechanics"
   b. Whether in the hands of those who took his insistence that mechanics be rooted in metaphysics seriously, or in the hands of those who preferred to divorce mechanics from metaphysics

2. Part of legacy: the notion of a conservation principle -- some quantity the total amount of which must remain constant throughout the universe
   a. For Descartes, conservation of total motion, owing to fluid-filled universe and constancy of God
   b. A sidelight of the mechanical philosophy: some quantity being exchanged while keeping the total constant a requisite for a mechanical universe!
   c. (Give some thought to the evidence problem in establishing any such conservation principle)
3. Part of legacy: idea that all curvilinear motion requires some sort of intervening action to prevent it from being rectilinear (III- 56-59), authorizing an inference from the contrapose of inertia
   a. Descartes' chief contribution to our principle of inertia
   b. Curvilinear motion involves a "centrifugal" (the word is Huygens's) tendency or endeavor -- *conatus* -- that must be counteracted to maintain curvilinearity
   c. A source of confusion, originating in Descartes, for, as we shall see below, he speaks both of a tendency of motion to continue in a straight line and a radially outward tendency
4. Part of the legacy: proposal that the endeavor to recede from the center can be measured by the tension in e.g. the sling or rope restraining the object!

   "We see, too, that the stone which is in a sling makes the rope more taut as the speed at which it is rotated increases; and since what makes the rope taut is nothing other than the force by which the stone strives [*conatur*] to recede from the center of its movement, we can judge the quantity of this force by this tension" (III, 59) [Millers' translation]

   a. Descartes says nothing about how to measure the tension in the rope
   b. But the science of statics did provide ways of measuring the tension in ropes in e.g. pulleys, so that the suggestion was not off-the-wall at all, as we shall see below and later in the course
   c. For both Huygens (1659) and young Newton (ca. 1666) independently picked up on this idea, leading them into the modern mathematical solution for uniform circular motion
5. Part of legacy: the importance of the mechanics of impact
   a. In mechanical philosophy the only forces are ones of contact
   b. Hence the laws of impact become laws of motion
   c. A great deal of attention given to these laws over the 20 years or so following Descartes' death, by such notables as Huygens (mid-1650s), young Newton (mid-1660s), Wallis, and Wren
   d. Usually restricted to the laws of head-on impact of spheres -- just the simplest case
   e. {Given the diversity of shapes of particles in Descartes' scheme of things, clearly need a generalization to other forms of impact as well}
6. Descartes also had a notable effect on the already widespread discussions of the mechanism of gravity among the adherents to the mechanical philosophy
   a. Heaviness -- the tendency to fall -- the prototypical natural quality which mechanical philosophers had to replace by a contact mechanism

b. Descartes' idea of some sort of vortex motion caught on widely

c. Question: how far does the effect extend above the surface of the earth, and is it uniform or does it diminish with distance

(1) Descartes thought this should be settled by experiments

(2) As we shall see, others tried to do so

d. Question: is gravity truly directed radially toward the center of the earth, and if so why

(1) Descartes had to fashion a special explanation for why a vortex that moves in parallel with the rotation of the earth on its axis does not produce a gravitational effect directed toward the axis

(2) Others found his explanation inadequate, leading to alternative versions of the vortex theory of gravity

7. Descartes' views about gravity challenged Galileo's (and the earlier Beeckman-Descartes) account of vertical fall

a. Descartes: once body reaches high enough velocity, effects of vortex on its top and bottom become equal, giving a terminal velocity after short distance of fall

b. Independence of weight from freedom of globules to pass through lower density bodies

c. Account directly challenges idea of separating fall in absence of air resistance from resistance effects -- a false dichotomy on Descartes' view

8. Finally, as is already clear, Descartes' mechanics engendered interest in the motions of fluids, especially the vortex motion of fluids

a. Contrast between isolated bodies contacting one another and bodies surrounded by fluid contacting one another

b. On Descartes' view former a conceptual idealization with no counterpart ever in reality

E. The Problem Addressed by the Vortex Theory

1. To begin assessing the adequacy of Descartes' foundations of science and the value of his top-down approach, we need to turn to his substantive science

a. In particular, to the vortex theory of planetary motion, which is really part of a broader, comprehensive vortex theory of the entire celestial realm

b. For this is the specific scientific theory put forward in the *Principia* that had by far the most influence

2. This theory is also something that is different from and complements the various efforts of Kepler and Galileo

a. Kepler and Galileo offered accounts of our planetary system, but not remotely as extensive in scope as Descartes'

b. Both of them, like Descartes, were preoccupied with settling the issue raised by the Copernican system, but Descartes' goal clearly did not stop with this or with orbital motion