CHAPTER 1

NEWTON'S *De Gravitatione* ARGUMENT AGAINST CARTESIAN DYNAMICS

This chapter, and chapter 2, explore the ontological and methodological evolution of Newtonian, Neo-Newtonian, and Leibnizian concepts of space and time. These concepts will form the foundational basis, and comparative starting point, for the eventual construction of a Cartesian spacetime in later chapters. However, in order to adequately ascertain the basic ingredients of a spacetime modeled on Descartes' physics, we will need to briefly examine the genesis of Newton's spatiotemporal views, since these beliefs constitute the backdrop of Newton's famous argument against Cartesian space and motion. A short sketch of the relational theory of space and motion postulated by Descartes, especially as viewed within the context of the Cartesian theory of dynamics,[1] will be presented in chapter 1, so that the source of Newton's criticisms (also presented in chapter 1) will become readily apparent. (An in-depth examination of Descartes' theory will form the subject of Part II.) As mentioned in the Introduction, it is important to trace the precise implications of Newton's argument, since each relationalist theory we will examine will constitute a different attempt to answer the same Newtonian challenge. In chapter 2, consequently, I shall provide an extensive analysis of the details and adequacy of the various Neo-Newtonian and relationalist theories of space and time developed in the wake of Newton's initial hypothesis. These latter theories warrant our attention, for they strive to correct the perceived deficiencies intrinsic to Newton's original formulation of absolute space and time. Finally, in the process of discussing the merits of both absolute and relational theories in chapter 2, I intend to put forth an argument claiming that, in a sense crucial to the analysis of the motions of bodies, there is something essentially correct with Newton's demand for absolute space. This argument, although presented somewhat tentatively here, will assume greater proportions and significance as the difficulties involved in shaping a consistent Cartesian dynamics become more apparent with each succeeding chapter. Ultimately, we will attempt to determine if a committed Cartesian can accept this "correct" aspect of Newton's argument while still remaining loyal to Descartes' conception of relational motion.

1.1. The Two Trends in Cartesian Natural Philosophy

Among Descartes' numerous conjectures on the nature of space and time, the relational theory advanced in the *Principles of Philosophy* (published in 1644) is by far his best known and most influential contribution to this ancient puzzle. Although a more in-depth discussion of these issues will arise in the following chapters (namely, Part II), Descartes essentially accepted the Aristotelian doctrine (favored among the scholastics) that "place" denotes the boundary between an object's surface and the surface of the material bodies contiguous with that object, while motion is "*the transfer [translatio] of one piece of matter or of one body, from the neighborhood [vicinia] of those bodies immediately contiguous to it and considered at rest, into the neighborhood of others.* (Pr II 25)"[2] Of course, these assertions make sense only when they are conjoined with two further Cartesian doctrines: (1) that a body's matter is "identical" with its spatial extension (although they are conceptually distinct, see Pr II 10), and (2) the whole of space is filled with matter (Pr II 16). Relationalism enters this picture in the following manner: provided a universal plenum (i.e., a universe completely packed with matter), and his definition of "place" as the relative boundary between contained and containing bodies, he reasons that the stipulation concerning whether it is the contained or containing body that is really "at rest" is purely arbitrary, since "we cannot conceive of the body AB being transported from the vicinity of the body CD without also understanding that the body CD is transported from the vicinity of the body AB (Pr II 29)"; and thus, "all the real and positive properties which are in moving bodies, and by virtue of which we say they move, are also found in those [bodies] contiguous to them, even though we consider the second group to be at rest. (Pr II 30)".

Basically, in the relational theory we are considering, "motion" and "rest" are only meaningful or significant when presented as a velocity or acceleration difference (or lack there of) among bodies. But, a velocity difference is ambiguous with regard to the assignment of *individual* component velocities. If, for example, the velocity difference among two sailing ships totals 25 knots, it may be the case that one ship is completely stationary while the other moves the stated amount, or that both ships are moving at some specific velocity whose combined total equals 25 (say, 15 and 10, respectively). In such a scenario, an "absolute" or "actual" determination of each individual object's state of rest or motion is just not possible. This theory, which has attracted many adherents both before and since Descartes (Aristotle, Ockham, Leibniz, Mach, etc.), displays a number of admirable features. Principally, since the only observable motions in our universe seem to be the relative velocity and acceleration differences among material bodies, relationalism nicely aligns its conceptual apparatus and ontology with the content of experience. As a result, relationalists need not concern themselves with such notions as "absolute rest" or "absolute velocity" that may prove empirically unverifiable.

Unfortunately, in both the *Principles of Philosophy* (and his earlier *The World*), Descartes advocates a series of laws on the nature of motion which not only appear to contradict this relational view, but which provided Newton with the model for what was eventually to become the focal point of his own laws of motion: "When a body is moving, even if its motion most often takes place along a curved line . . . , nevertheless each of its individual parts tends always to continue its motion along a straight line."[3] Finished in 1633 (eleven years before his *Principles of Philosophy*), *The World* constitutes Descartes' greatest contribution to the development of dynamics (the branch of mechanics that deals with the motions of bodies under the action of forces); for, as revealed in the quotation, Descartes offers one of the earliest known hypotheses identifying the phenomenon of centrifugal force as occasioned by the "tendency" of bodies to move (inertially) in straight lines.[4] Alongside his thoroughgoing Aristotelian relational account of motion, consequently, Descartes also supported the existence of uniform inertial motion (i.e., a velocity that is constant and does not change, or accelerate) as an integral component of his world view. The second law of motion in the *Principles*, for instance, is identical to the quotation provided above: "All motion is, of itself, along straight lines; and consequently, bodies which are moving in a circle always tend to move away from the center of the circle which they are describing (Pr II 39)".

As discussed, it is not possible in a relationalist theory to ascribe motion of fixed magnitude and direction to a single body. Yet, Descartes proposes an hypothesis on the nature of motion in *The World* which practically embraces the notion that bodies can exhibit determinate individual velocities: "As for me, I conceive of [motion] none except which is easier to conceive of than the lines of mathematicians: the motion by which bodies pass from one place to another and successively occupy all the spaces in between (Descartes 1979, 63)." This geometric and seemingly "Newtonian" analysis of motion could not be more removed from his subsequent relational allegations in the *Principles*(as described above). Remarkably, one also discovers in *The World* two famous philosophical doctrines that are seemingly synonymous with Cartesianism: the identification of spatial extension as the sole property of matter (35-36), and the rejection of a matter-less void space (20-21). Faced with these apparently contradictory assertions, it seems that one must admit the hidden influence of a geometric, non-Aristotelian factor in Descartes' intuitions about place and motion.[5]

This underlying tension in Descartes' theory of motion is a problem which inevitably arises in the course of any examination of Cartesian natural philosophy. Among the many factors that might have precipitated Descartes' inconsistency, the disclosure of Galileo's condemnation by the Inquisition for teaching anti-Aristotelian, anti-relationalist physics has been assigned a prominent role.[6] Regardless of it source, Descartes' mature views on the nature of space and the phenomenon of motion, as put forth in the *Principles of Philosophy* (and defended throughout the remainder of his life), incorporate a set of apparently non-relational *laws* of motion (originally presented in *The World*) alongside a relational *theory* of motion. Despite the repeated charges of "inconsistency" and "incoherence" that are inevitably leveled at this strange marriage of seemingly opposing doctrines, Descartes' theory presents a paradigm example of the difficulties inherent in any attempt to reconcile an Aristotelian theory of place and relational motion with a (dynamical) theory of material body interactions. In chapter 2, we shall return to the investigation of the Cartesian theory; but, in the remainder of this chapter, we need to examine the argument that Newton specifically designed to exploit the apparent dichotomy of purpose exhibited by Cartesian physics.

1.2. Newton's Argument Against Cartesian Relationalism

Isaac Newton explicates his conception of space and time primarily in two documents: the relatively unknown *De gravitatione et aequipondio fluidorum,*[7] and the monumental *Philosophiae naturalis principia mathematica.*[8] Of the two, *De gravitatione* is by far the most revealing; since, among other things, the belated introduction of this early paper into the philosophical literature has finally implicated Descartes, and not Leibniz, as the intended target of his arguments against the relational theory of space and time.[9] In *De gravitatione,* Newton criticizes the divergent trends in Descartes' thought by demonstrating their basic incompatibility in several important respects. To demonstrate this point, we will exclusively explore an argument which, besides criticizing Descartes, likewise discloses the conceptual foundation of Newton's own spatiotemporal views. After disclosing the details of Descartes' theory, Newton states:

> I say that thence it follows that a moving body has no determinate velocity and no definite line in which it moves. And, what is worse, that the velocity of a body moving without resistance cannot be said to be uniform, nor the line said to be straight in which its motion is accomplished. . . . But that this may be clear, it is first of all to be shown that when a certain motion is finished it is impossible, according to Descartes, to assign a place in which the body was at the beginning of the motion; And the reason is that according to Descartes the place cannot be defined or assigned except by the position of the surrounding bodies, and after the completion of a certain motion the position of the surrounding bodies no longer stays the same as it was before. . . . Truly there are no bodies in the world whose relative positions remain unchanged with the passage of time, and certainly none which do not move in the Cartesian sense: that is, which are neither transported from the vicinity of contiguous bodies nor are parts of other bodies so transferred. . . .
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> Now as it is impossible to pick out the place in which a motion began, for this place no longer exists after the motion is completed, so the space passed over, having no beginning, can have no length; and hence, since velocity depends upon the distance passed over in a given time, it follows that the moving body can have no velocity, just as I wished to prove at first. Moreover, what was said of the beginning of the space passed over should be applied to all indeterminate points too;

and thus as the space has no beginning nor indeterminate parts it follows that there was no space passed over and thus no determinate motion, which was my second point. It follows indubitably that Cartesian motion is not motion, for it has no velocity, no definition, and there is no space or distance traversed by it. So it is necessary that the definition of places, and hence of local motion, be referred to some motionless thing such as extension alone or space in so far as it is seen to be truly distinct from bodies. (Newton 1962a, 129-131)

Newton puts forth a number of important claims in this crucial passage. In order to better reveal its basic assumptions and form, it would be best to analyze his argument by detailing each important step. In what follows, premises (1) through (5) are all assumptions:

(1) Descartes' law of inertial motion: All bodies tend to remain at rest or move in rectilinear paths at uniform velocity. This is a conjunction of Descartes' first and second laws (Pr II 37-39).

(2) Descartes' relational theory of place and motion: This premise entails that all places and motions are determined relative to other contiguous material bodies.

(3) Descartes' plenum theory of matter: All of space is filled with material bodies. This premise is not essential.

(4) Observation: All the material inhabitants of the universe constantly alter their relative positions (relative to one another).

(5) Both straight line motion and velocity (which is described as *distance* divided by time) require a temporally fixed path of determinate length: That is, in order to determine a body's velocity and line of motion, the places successively occupied by the moving body, which together comprise a definite length, must remain unaltered over time.

(6) From (2) through (5): Straight line motion and velocity cannot be determined in the Cartesian universe. More explicitly, due to the continuous motion and scattering of the contiguous bodies responsible for defining relative place, the trajectory or path of a moving object can exhibit no well defined length and, thus, no well defined velocity (or "speed", since Cartesian motion is a scalar quantity, and thus not coupled to a definite direction—see chapter 3).

(7) Contradiction from (1) and (6).

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