CHAPTER 4

MATTER AND SUBSTANCE IN THE CARTESIAN UNIVERSE

The overall goal of our investigation is to explore possible formulations of a Cartesian physics that can circumvent some of its well-known internal inconsistencies, such as those raised in Newton's famous argument against Descartes' theory of space and motion. However, in order to investigate the prospects of successfully devising such a response, we will need to explore further the details of Descartes' laws of nature. While chapter 5 will investigate the origins and function of the Cartesian conservation law for "quantity of motion," the present chapter will examine the conditions or stipulations that Descartes appended to his collision rules, as well as the specific character and content of Descartes' hypotheses of matter and (material) substance. Up to this point, it has been largely assumed that Descartes' laws, and his corresponding concept of matter, will present no special difficulties when transferred to a plenum setting (i.e., his matter-filled world). Yet, as will be shown, this marriage presents a number of obstacles that threaten to undermine Descartes' entire project. I will argue, nevertheless, that many portions of Descartes' major scientific treatise, the *Principles of Philosophy,* demonstrate that he was fully aware of, and capable of addressing, many of the difficulties brought to light by the conjunction of these seemingly incompatible partners, i.e., his quasi-absolutist natural laws and a plenum environment.

4.1. "Perfect Solidity" and The Natural Laws

Among the ideal conditions that appear in his *Principles of Philosophy* (Pr II 37-52), Descartes remarks that his seven rules on the impact of material bodies "could easily be calculated . . . if [the two colliding bodies] were perfectly solid (*durus*). . . (Pr II 45)." Although this stipulation was intended to assist in the application of the collision rules (as instances of his third natural law), the complex and puzzling concept of "perfect solidity," or "perfect hardness," is perhaps also notable for having generated several divergent interpretations among recent commentators. In some instances, "perfect solidity" has been translated into the modern dynamical locution "perfect elasticity," which denotes a class of material bodies that return to their original shape, volume, etc., after deforming under impact.[1] The translators of the first complete English edition of the *Principles,* V. R. Miller and R. P. Miller, for example, assume that Descartes had elasticity in mind in the passage quoted above.[2] While it is true that most commentators regard Cartesian bodies as "inelastically hard" (i.e., they do not alter their shape during collision), even a few of these scholars have been unable to completely resolve their doubts. For instance, R. S. Woolhouse has recently concluded that "since the 'before and after' of a perfectly hard collision is the same as the 'before and after' of a perfectly elastic one, there is some justification for the sometimes-made assumption that by 'hard' [solid] Descartes *really* means 'elastic'."[3] Notwithstanding the merits of this elastic/inelastic controversy, it would appear that such disputes overlook a more fundamental question that lies at the heart of the "perfect solidity" issue: Does Descartes' use of the "perfect solidity" concept encompass only the interactive, *collision* properties of bodies (i.e., how they behave under impact), or are other individual, non-interactive factors implicated as well, such as their internal composition and configuration of elementary particles? Contrary to the prevailing viewpoint (or lack there of) among commentators, we will present a case for the latter interpretation of perfect solidity, claiming that it constitutes the only means of correlating much of the information found in the latter portions of the *Principles* with the natural laws put forth in Pr II (Part II of the *Principles*). Despite its apparent connotations, "perfect solidity" pertains to the internal constitution of the basic particles that make up macroscopic bodies, and only indirectly the dynamic properties manifest in bodily collisions.

In order to demonstrate that Cartesian solidity is not merely a stipulation on bodily collisions, however, we will need to explore the interrelationship between the Cartesian conserved property of quantity of motion (often described as "size times speed") and the three bodily properties of volume, surface area, and quantity of matter. The specific function of these latter three properties is an issue that has received scant attention among Cartesian scholars, but it is crucial to a full understanding of Descartes' physics. For example, in the canonical presentation of the conservation law for the quantity of motion, Descartes' *Principles* specifically incorporates bodily surface area as a key factor in the determination of quantity of motion:

> We must however notice carefully at this time in what the force of each body to act against another or resist the action of that other consists: namely, in the single fact that each thing strives, as far as is in its power, to remain in the same state . . . . One which is at rest has some force to remain at rest, and consequently to resist everything which can change it; while a moving body has some force to continue its motion, i.e., to continue to move at the same speed and in the same direction. This force must be measured not only by the size of the body in which it is, and by the [area of the] surface which separates this body from those around it; but also by the speed and nature of its movement, and by the different ways in which bodies come in contact with one another (Pr II 43).

Thus, the quantity conserved in the motion and impact of bodies, which Descartes refers to as "quantity of motion," is determined by three factors: size, surface area, and speed (where speed is conceived as a non-directional scalar property, see chapter 3). Although the role of surface area is not revealed at this stage in the *Principles,* the derivation of his natural laws in Pr II apparently equates a body's size with its volume, and its quantity of motion with the product of its size and speed (e.g., "when one part of matter moves twice as fast as another twice as large, there is as much [quantity of] motion in the smaller as in the larger," Pr II 36). Given his thesis that spatial extension (in three dimensions) constitutes the essential property of material substance (Pr II 11), it is probably not surprising that the alleged identification of Descartes' term "size" with "volume" is often accepted as an elementary fact of Cartesian science.[4] Nevertheless, it is also true that Descartes' conservation law implicates both size *and* surface area in the determination of quantity of motion, two properties whose exact interrelationships, and hence contribution to the conservation law, are never clearly detailed in the Cartesian theory of matter.

The problem of harmonizing Descartes' sporadic references to surface area, volume, and quantity of matter with his principal use of the term 'size' has long been a source of irritation among Cartesian scholars. Many who are aware of the ambiguous contribution of Cartesian matter to the natural laws have only mentioned this difficulty in passing, since their main research concerns others aspects of Descartes' physics. To illustrate, in an important essay on Cartesian force, M. Gueroult's only reference to these issues is the observation that "the notion of mass identified with volume remains very obscure in Descartes."[5] In other cases, scholars will draw attention to the imprecise meaning of Descartes' term by placing it in quotation marks (i.e., "size"), as does A. Gabbey in the following: "for Descartes, . . . the force of motion of a body, . . . is the product 'size' × speed . . . ."[6] Overall, the sentiment of many of these Cartesian researchers is probably best captured by D. M. Clarke's remark that "the details of [Descartes'] theory are never sufficiently developed, so that one finds the same rather vague references to size, surface area, resisting media, and speed . . . ."[7]

Nevertheless, the details of Descartes' theory are less vague than most commentators have assumed. To demonstrate this point, sections 4.1.1 through 4.1.4 will examine how the bodily properties of volume, surface area, and quantity of matter are integrated by Descartes' concept of perfect solidity. On the basis of this discussion, we will then return, in section 4.1.5, to the question posed at the outset: i.e., Is "perfect solidity" chiefly a collision, or composition, property of macroscopic bodies?

4.1.1. Rarefaction and Condensation.

Descartes' definition of solidity first appears in Pr II of the *Principles,* Articles 54: "Those bodies whose particles are all contiguous and at [relative] rest, are solid." In this passage, "contiguous" is the term requiring further elaboration, since the appeal to the "relative rest" of the particles pertains to Descartes' rejection of a binding force among the infinitely-divisible particles of matter (Pr II 20, 55). Essentially, Descartes treats the observed phenomenon of varying bodily density, or, as he phrases it, "solidity," through an appeal to the spaces between the particles of matter. With respect to those processes which either decrease or increase the size of material bodies (labeled, respectively, rarefaction and condensation), he states: "rarefied bodies are those with many spaces between their parts which are filled by other bodies. And rarefied bodies only become denser when their parts, by approaching one another, either diminish or completely eliminate these spaces; . . . (Pr II 6)." Thus, bodies whose particles are contiguous (i.e., they are not separated by an influx of foreign matter) are deemed "solid" (see Figure 13). Descartes evidently found these natural processes of varying density rather disturbing, for they "might lead one to doubt whether the true nature of body consists in extension alone," a remark that also explains their presence at so early a stage in the *Principles*. Yet, only in Pr III 48-52, are we first introduced to the hierarchy of material elements responsible for the swelling and shrinking of these large macroscopic bodies. Briefly, Descartes procures a threefold subdivision of matter in order to explicate the underlying mechanisms that operate his matter-filled, or plenum, world. These basic particles, largely differentiated by size and function, are: (i) the large, macroscopic third elements of matter, and (ii) the much smaller, globule-shaped second elements of matter; while the minute debris formed from the collisions of the second and third elements, known as (iii) the first elements of matter, serve to fill the lacunae manifest between these larger particles (see Figure 14).

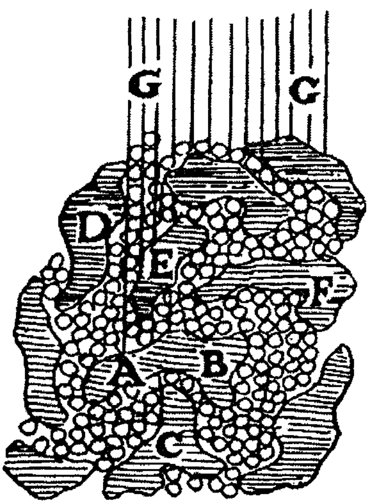

Figure 13. A illustration from the *Principles* that reveals the many smaller particles inside the pores of larger bodies.

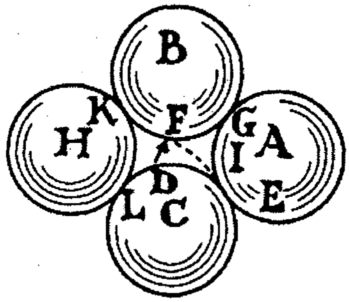

Figure 14. The constantly moving first elements of matter fill in the gaps between the larger elements, such as the triangular space FGI between the secondary globules A, B, C, and H (AT III 92).

In Pr III of the *Principles,* Descartes presents a somewhat more elaborate analysis of the problem of solidity. Quite possibly, he felt compelled to furnish a systematic explanation of this phenomenon after reflecting upon the variety of diverse behavior produced by identically-sized bodies in resisting or sustaining motion—behavior which today we would call inertial effects. That is, there often exists a disparity among bodies of the same spatial volume, such as two identically sized globes composed, respectively, of gold and wood, in resisting changes to their states of motion (e.g., one is much harder to move than the other). One of the principal motivating factors in the formulation of the Cartesian theory of solidity is the need to explicate the origin of these "inertial" effects. In fact, a discussion of the motions of celestial bodies occasions Descartes' next attempt at a definition: "the solidity of [a] star is the quantity of the matter of the third element, . . . in proportion to its volume and surface area (Pr III 121)." As defined, solidity is thus a function of three variables: quantity of third element matter, surface area, and volume. Since the distinction between these three quantities, and their role in affecting density, is often misunderstood, we shall examine this three-part interrelationship below.

4.1.2. Volume, Quantity of Matter, and the Agitation Force.

At one point in the examination of solidity, Descartes utilizes his ratio of quantities to resolve the problem, just described, of divergent motions that originate from bodies of equal volume. He explains:

> Thus, here on earth, we see that, once moved, gold, lead, or other metals retain more agitation, or force to continue in their movement, than do pieces of wood or rocks of the same size and shape; and consequently metals are also thought to be more solid, or to contain more matter of the third element and smaller pores filled with the matter of the first and second elements (Pr III 122).

Descartes' remarks contain an implicit conjecture on the origins of inertial effects (although, as previously noted, Descartes did not hold the modern

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