PARTICLES AND MOTION IN SPINOZA'S PHYSICS

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B.A., University of British Columbia, 1960

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

M.A.

in the Department

of

PHILOSOPHY

We accept this thesis as conforming to the

required standard

THE UNIVERSITY OF BRITISH COLUMBIA

SEPTEMBER, 1969

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Date October 1 1969

ABSTRACT

The central aim of my thesis is to enquire into Spinoza's theory of the structure of the physical universe. It is generally accepted that from a scientific point of view Spinoza regarded the universe as consisting of particles in motion. My major concern is with the nature of these particles and what role they play in his cosmology. My basic method of enquiry is to consider, as far as this is possible, Spinoza's statements about the structure of matter as a scientific theory, a system of physics.

Chapter Two is a brief survey of Spinoza's scientific activities, by way of providing background. In Chapter Three I explore the physical theory presented in Part Two of the Principles of Cartesian Philosophy with particular emphasis on the basic premisses of that theory, and the problems arising from those basic premisses. In Chapters Four, Five, and Six, the physical theory of the Ethics is discussed, with particular attention to Spinoza's theory of individuals and his ideas on motion. Chapter Seven is a fairly detailed discussion of the nature of the simplest bodies in Spinoza's system. Chapter Eight is a discussion of Spinoza's concept of the universe as a system composed

of particles in motion, with particular emphasis on his ideas on the continuum. My major conclusion is that as far as scientific explanation is concerned, the Spinozistic physics is very similar to the Cartesian physics as presented in the Principles of Cartesian Philosophy. This conclusion is based on five consideration: (1) the general character of the physics of the Ethics is quite compatible with the Cartesian physics with one apparent exception: I give an explanation of this apparent discrepancy; (2) Spinoza's deep concern with the problems of the continuum can only be explained if the basic premisses of his physics are the same as that of the Cartesian physics; (3) the same applies to his denial of the existence of the vacuum; (4) there is nothing that indicates that Spinoza's scientific method if radically different from that underlying the Principles of Cartesian Philosophy; (5) the one instance of Spinoza's outrightly condemning the Cartesian physics is based on a fundamental metaphysical issue and has no direct bearing on that physics qua physics.

The major implication of my conclusion is that many of Spinoza's points of doctrine cannot be fully understood unless they are interpreted in the context of the Cartesian cosmology.

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ACKNOWLEDGEMENT

I am grateful to Professor Remnant for his suggestions and criticisms, and to the University of British Columbia for the financial assistance which made my studies possible. I especially wish to thank my wife, Jean, for her help and encouragement.

CHAPTER I

INTRODUCTION

The basic purpose of this thesis is to explore the character of the primary particles and of motion in Spinoza's system, and the role they play in his cosmology. As far as I have been able to discover, this part of Spinoza's theory has not received a very close scrutiny, and yet, as I will show, a number of interesting facets of Spinoza's thought are revealed when his ideas on the foundations of physical science are explored.

A large quantity of commentary is available on Spinoza's physics from a metaphysical point of view, that is, as a very general scheme for looking at reality; but his physics as a detailed explanation of the physical phenomena does not seem to have had the benefit of a close examination. This concerns particularly the nature of the simplest bodies and motion in his system; that Spinoza viewed the physical world in terms of particles in motion seems to be generally agreed on, but exactly how his scheme works in detail, and precisely what the nature of these particles is, remains obscure. My reading of Spinoza's writings, especially his correspondence, has convinced me that he had always in mind the intention to set up a detailed science of mechanics, or at least

to lay a solid foundation on which such a science is to be based. My emphasis, therefore, will be on treating his ideas in that light, to consider his scheme, as a program for physical science.

A formidable obstacle in the way of this kind of project is the paucity of available material. The three principal sources are the Principles of Cartesian Philosophy (hereafter to be abbreviated as "Principles"), a few letters and a few pages in the Ethics. The Principles, published in 1663, has the serious disadvantage as a source, in that it purports to be merely an exposition of Descartes's philosophy, and supposedly does not represent Spinoza's own ideas. The Ethics , which can be taken as representing his ideas in their most complete and fully developed form, lamentably is written in a highly condensed form, and contains very little in the way of discussion, comment or explanation. The earlier letters, especially those addressed to Oldenburg and written in April 1662, April 1663, and June 1663, contain extensive discussions, but their value is somewhat limited with respect to Spinoza's later ideas. The later letters contain only a sentence here and there, which are useful as clues, but provide little concrete information. Hence I have taken the physical theory of the Ethics as the key source of information,

and the final arbiter on what Spinoza's latest and most fully developed views are. However, I have devoted a considerable amount of attention to the physics of the Principles, the reasons for which I have outlined in the third chapter, which contains a discussion of that physics.

This thesis is necessarily limited in several ways. For instance, I have largely bypassed a discussion of Spinoza's theory of scientific method, which of course is rather important in its own right, but which deserves a more thorough discussion than I could possibly give it here. A full treatment of this topic can be found in Richard McKeon's[1] book, which I have found to be an invaluable source of ideas; the chapter on Descartes and Spinoza and the chapter on experimental science are especially useful. McKeon bases his discussion of Spinoza's scientific method largely on the dispute between Robert Boyle and Spinoza on the nature of nitre and the character of hardness, softness and fluidity. This dispute, which is found in the correspondence with Henry Oldenburg, has not been analyzed in detail in this thesis, for several reasons; one is that it is rather involved, especially because of Oldenburg's role as an intermediary in the dispute. Second, the dispute dates from the same period as the writing of the Principles, and hence its usefulness as information on Spinoza's later ideas is somewhat limited.

Third, its chief usefulness is in the area of scientific method, which is outside the scope of this thesis, although the subject cannot be avoided altogether.

Another limitation which I have had to set myself in the writing of this thesis consists of avoiding a discussion of Spinoza's philosophy in broader terms. Plenty of commentary on that subject exists already, and, besides, my purpose is to explore Spinoza's physics in order to shed light on his larger scheme, and not vice versa. Nonetheless, I have had to take certain parts of his doctrine for granted as common knowledge. For instance, I have taken for granted his points of doctrine that there is no plurality of substances, that there is a perfect parallelism between the attributes of Thought and of Extension, and that there is no creator outside of substance. A reference to Spinoza's general philosophical system is often necessary to clarify some of the things he says, especially what he says in the Ethics, but I have tried to avoid misrepresenting his doctrine, and putting too much weight on specific points of doctrine. I have taken care to avoid becoming entangled in the philosophical disagreements between Descartes and Spinoza. Throughout this work, references to Descartes are almost exclusively limited to the material of the Principles; when I have occasion to refer to the Cartesian physics, I shall be

referring to the physics of the Principles, leaving it deliberately unspecified to what extent that physical theory represents Descartes's ideas. My aim is to discuss Spinoza's ideas, not those of Descartes's.

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[1]See McKeon, pages 137-157. (All references are to the appended list of works).

CHAPTER II

SPINOZA'S SCIENTIFIC ACTIVITIES

Spinoza was undoubtedly a well educated man in scientific matters. The list of books left by him in his library at his death is good evidence of this (I have appended this list, together with some comments). He was acquainted with almost all of the scientific developments of his time, and he was always asking his correspondents for information about the latest experiments and discoveries. He was thoroughly familiar with the scientific ideas of Descartes, whose theories were very much a part of the mainstream of the scientific thought of that age. His dispute with Robert Boyle on the topic of the redintegration of nitre shows us a man who had a good understanding of the nature of Boyle's scientific work; his criticisms of Boyle, although not completely without flaws, were well founded and quite sophisticated.[1]

Aside from a general interest in the science of his time, Spinoza was also to some extent more directly involved. Suprisingly, for a man who is labeled a rationalist philosopher[2], he carried out a small amount of experimental work. There is first of all the hydrostatic experiment described in the letter to Jarig Jelles of September 1669, which is fairly elaborate and carefully

set up. The first part of the experiment is designed to show that water in a series of interconnected tubes will reach the same level in those tubes. The second half of the experiment is better described as a hydrodynamic experiment, because it deals with rates of flow of water. The second part of the experiment is rather interesting in that the experimental apparatus used by Spinoza is quite suitable for the investigation of momentum, velocity and acceleration. As a point of general interest I have appended a more detailed discussion of the experiment (see Appendix B).

Another set of experiments is connected with the nitre dispute; the description of these is found in the letter of April 1662 to Oldenburg. These experiments are undertaken by Spinoza not so much out of what we might call sheer scientific curiosity, but to prove a certain point, the point being that his explanations of the character of nitre are at least as plausible as those of Boyle's, and that only very simple experiments are needed, rather than the elaborate ones that Boyle has performed. Accordingly, Spinoza's experiments are rather simple.

Another experiment which Spinoza describes, but does not perform, is mentioned in the letter of April 1662 to Oldenburg. Its purpose is to compare atmospheric

pressure in a horizontal plane with that in a vertical plane, which is done by taking measurements of the force required to pull apart two smoothly polished pieces of marble. This experiment may not be original with Spinoza, since mention is made of it by Descartes and others[3]; the point of interest is that he does not feel sufficiently curious about the result of such an experiment to execute it, it seems. This apparent lack of curiosity is evident in the other experiments as well; as soon as some point is sufficiently well established, in his opinion, Spinoza loses interest. What stands out clearly from Spinoza's experimental activities, is that as far as his own life and work is concerned, he does not attach a great deal of importance to experimentation. On the other hand, whether he thought that experimentation and observation were an essential element of scientific activity is out of the scope of this thesis to determine. He may have thought that experiments were very important while being content to let others carry them out, or he may have thought that experiments were incidental and served merely as an aid to thought. The evidence is somewhat contradictory on this point.

The major portion of Spinoza's scientific work was in the field of geometrical optics. His reputation in this area was well established and wide spread. Leibniz,

in a letter written in October 1671, says to him: "Among the other praises of you which fame has bruited abroad, I understand is your great skill in optics." Leibniz sends along a technical paper for comment, and they discuss the problem of spherical aberration in lens systems. There are numerous other items which attest to Spinoza's high level of competence in optical science. In a letter to Jarig Jelles, dated March 25, 1667, he discusses, geometrically and in detail, how the eye sees an image produced by a telescope. In a letter to John Hudde, June 1666, he describes and compares the optical properties of various lens shapes. There are also a number of items dealing with practical problems of lens grinding, one of which should be reported if only because it is amusing. Huygens has constructed a lens polishing machine[4], but Spinoza is opposed to automation, and believes that, although he is not acquainted with such a machine, manual methods are preferable, because "... experience has taught me sufficiently that in spherical tools it is safer and better for glasses to be polished with a free hand than by any machine".

Spinoza's only major work in optical science is his Treatise on the Rainbow[5], which is a detailed and carefully worked out mathematical derivation of the angular sizes of both primary and secondary rainbows. It is really

more an exercise in geometry and trigonometry, than a work of physical science, and indeed, the work is presented to the reader as a means of testing and improving his mathematical ability, although it also contains a brief explanation of the cause of the colours of the rainbow. The explanation, which Spinoza attributes to Descartes, is in terms of the different degrees of strength of colours, red being the strongest, and violet, on the other end of the spectrum, the weakest. Of these rays of light which have to travel through the greatest thickness of water, the weaker colours are sorted out, and only the stronger get through. Rays which travel through a shorter distance in water show the other colours more strongly. The theory as it is presented in the treatise is somewhat vague and is not developed in detail, but it is a fairly plausible explanation of colour dispersion. Newton, a few years later, gave the correct explanation, namely that white light is composed of, or can be resolved into, light of different colours, each colour having a slightly different index of refraction. In retrospect it seems that Spinoza, possessing a sound scientific background and undoubted mathematical competence, was in a good position to have made this discovery himself, but likely he felt that the other explanation was quite adequate, especially since he praises Descartes in the <u>Treatise</u>

for having given it. Apart from the question of colour dispersion, the Treatise says nothing about the nature of light, although we may assume that Spinoza's theory of light was much the same as that of Descartes's[6].

The significance of Spinoza's work on optics lies in the fact that geometrical optics is a deductive science par excellence. From two simple, basic elements, the law of reflection, and the rules of refraction, and using only geometrical methods, it is possible to deduce a large number of complex relationships about telescopes, rainbows, and bent sticks in water. It is the science for which Descartes's famous identification of physics with geometry is closest to being true. It is a plausible conjecture that Spinoza visualized a physical science with the same elegance and precision that is characteristic of optics, a science based on a few axioms and definitions from which all the complex phenomena can be deduced.

All in all, Spinoza was right in the midst of things scientific, and in view of his involvement with the science of his day and his mathematical competence, as the Treatise on the Rainbow makes clear, it is rather surprising that his work did not have the scope and impact of the work of such men as Galileo, Descartes or Huygens. But the reason is not hard to find; for Spinoza science played only a subordinate role; his chief aim was the

improvement of the understanding in the most general sense and in his ambitious program scientific knowledge was considered as a means to an end only. We have a very good statement of this in his own words as found in The Improvement of the Understanding:

> Thus it is apparent to every one that I wish to direct all sciences to one end and aim, so that we may attain to the supreme human perfection which I have named; and, therefore, whatsoever in the sciences does not serve to promote our object will have to be rejected as useless.

Although in his time there was no sharp distinction made between the work of a philosopher and that of a scientist, it is safe to say, in retrospect, that Spinoza was first and foremost a philosopher and only incidentally, a man of science. His enterprise was to construct a scheme in which everything was explainable, and the patient ferreting out of "little" truths about the nature of things, perhaps best exemplified by the work of Boyle, was for him of secondary importance, although he was always an interested spectator of the activities of others in science.

Making a distinction between the work of a scientist and that of a philosopher is somewhat artificial, especially as applying to the seventeenth century. Spinoza's own work serves as a case in point: even though his overriding concern was for the larger more abstract issues, his intersts cover a wide spectrum, from the properties

of nitre to the nature of God. Nevertheless his work reveals an outlook and temperament quite different from that of such men as Boyle and Huygens. Hence, what is interesting about his scientific ideas does not lie so much in the general scientific activities referred to above, but in the more theoretical aspects of physical science, such as the structure of matter, the basic components of the physical universe, the fundamental elements of scientific explanation. In this connection, it is this theory of particles and motion which is of great interest, and it is this theory which is the main concern of this thesis.

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[1]See McKeon, page 156.

[2]The same is true of another rationalist, Descartes, who made observations on the passage of light rays through glass spheres in connection with this theory of the rainbow. See Scott, page 74.

[3]See Scott, page 12.

[4]See Wolf, pages 423-425.

[5]For comments on the authenticity of this work, see Gebhardt, pages 431-434.

[6]See Scott, pages 28-63.

CHAPTER III

THE CARTESIAN PHYSICS

Three considerations make the discussion of the Cartesian physics relevant to the topic of this thesis:

(a) The Cartesian physics is in some way also Spinoza's physics. Spinoza studied Descartes's theories very closely, and paid tribute to Descartes's intelligence and his keen mind[1]. The very fact that Spinoza wrote the Principles attests to his involvement with the Cartesian ideas, and while that work is supposed to represent Descartes's thought, and not Spinoza's, it is uncertain to what extent and how Spinoza's physical theories differed from those of Descartes. When the introduction to the Principles, written by Ludwig Meyer, is examined, we find that Meyer mentions the will, the intellect, the existence of thinking substance, the limits of human knowledge as topics on which Spinoza disagrees with Descartes. There is no mention of a divergence on such things as the nature of motion, the character of particles, scientific method, laws of motion, etc.. In the letter to Oldenburg, written in November 1665 (two years after the publication of the Principles), Spinoza says:

As to your next remark, that I hinted that the

> Cartesian laws of motion are nearly all false, if I remember rightly, I said that Mr. Huygens thinks so. Nor did I say that any law is false except the sixth law of Descartes, and even about that I said Huygens too is mistaken.

There are no clues anywhere in Spinoza's writings as to the exact point of dispute with regard to these laws of motion, with one exception, perhaps: in the Principles Spinoza is seen to amend Descartes's sixth rule of motion slightly. However, whether Spinoza regards the modified sixth law as true or not is impossible to determine, and hence, from this remark alone it must remain undecided exactly how Spinoza felt about the Cartesian physics.

(b) Spinoza's physics may well be regarded as a modification of the earlier physics. From the very fact that these two philosophers were so close together in time and that Spinoza was thoroughly versed in Descartes's theories, it is only natural to expect that Spinoza began where Descartes left off. Studying the ramifications of the Cartesian physics should be useful for the understanding of Spinoza's physics. Besides, there are a number of items which are common to both theories. For instance, Spinoza's treatment of hardness, softness, and fluidity in the Ethics fits in quite well with the physics of the Principles; in the dispute with Boyle, Spinoza gives theoretical explanations which are essentially Cartesian in character. Also, with regard to the existance of a

vacuum, and the nature of scientific method, there seems to be a great deal in common in their ideas.

(c) The Cartesian physics forms a useful frame of reference for the discussion of Spinoza's ideas. Descartes's cosmology and theories of matter were dominant at that time and had a powerful influence over men like Christian Huygens, to name one example; his vortex theory of planetary motion held sway for a long time, even after the appearance of Newton's theories. The Cartesian physics, then, is very much representative of the scientific ideas of that age, and as such is quite relevant to Spinoza's physics.

Because the scientific ideas of Descartes are not the central topic of this thesis, the discussion will naturally have to be somewhat limited. The most appropriate way of doing this is to restrict the discussion to the second and third parts of the Principles. Furthermore, I will discuss only those aspects of the Principles which have some bearing on the main topic of this thesis, namely the character of the particles and of motion in Spinoza's system. Of course in a sense all of the Principles is relevant to this topic, because Spinoza, even though he disagrees with Descartes on a number of things, in that work does not merely repeat Descartes, but works out the whole scheme in his own words. It is obvious that he

takes Descartes's physics quite seriously, and it is also clear that he doesn't intentionally include proofs that are logically unsound, so that even if the propositions are false in his opinion, the reasoning would still be of interest. However, in the main, the Principles is still a work on Descartes's physics, and therefore a discussion of certain problems would naturally tend to be merely a discussion of Descartes's ideas and would bring us no closer to understanding what Spinoza's ideas were. Therefore I have selected those problems for discussion which I think are relevant to the physics of the Ethics.

Because it is uncertain to what degree the physics of the Principles represents Spinoza's theory, I will refer to that physics simply as the "Cartesian physics", leaving it deliberately unspecified to what extent the "Cartesian physics" is also Spinoza's physics. By the term I shall not be referring to the whole of Descartes's theories of the physical world, which includes a large number of items not discussed in the Principles, such as the vortical theory of the solar system, the nature of heat and light, the three kinds of matter, gravity, etc..

The Principles, not counting the Cogitata Metaphysica, which is an appendix, is cast in the geometric form. Part

Two begins with a statement of nine definitions and twenty-one axioms; from these, with an occasional reference to Part One, a number of propositions are established. The basic assumption, axiom, or postulate[2] is that physical substance is extension. All the properties of bodies such as colour, hardness, weight, taste, warmth and coldness, etc., are secondary properties, dependent on the senses. Proposition 2 states: "The nature of body or matter consists in extension alone". The Corollary to this proposition sums up nicely the fundamental feature of the Cartesian physics; it states: "Space and Body are the same". What makes the Cartesian physics so radically different from the Newtonian[3] system, is the treatment of the concept of mass. In the Newtonian system two distinct quantities apply to bodies, their volume and their mass or quantity of matter, so that solid bodies can have the same size but different weight and mass, or vice versa, and a given body can change its volume without changing its mass or weight, i.e. can change its density. In the Cartesian system, only one quantity applies to solid body. This is clearly expressed in the Corollary to Proposition 4:

> Bodies which occupy an equal amount of space, as for example some gold and brass, have an equal amount of matter or of corporeal substance.

The mass of a body is the same as its true size, the volume

it would occupy if the material of the body were redistributed so that there were no pores or interstices left. To explain the commonly observed phenomenon of condensation and rarefaction, the example of a sponge is used in the demonstration to Lemma 2. When a body is seen to change its volume, it is actually only changing its exterior dimensions, while the interstices between the parts of the body become larger or smaller.

The identification of space with body has the immediate consequence that a vacuum does not exist. A vacuum is defined as space without body, and since space is body, this is self-contradictory. It is important to note that the non-existence of a vacuum is not merely a contingent fact about nature, it is a logical truth derived from the meaning of the basic terms. The vacua produced experimentally by such people as Von Guericke and Robert Boyle are only apparent vacua. Descartes, in his Principles of Philosophy, (not to be confused with Spinoza's Principles of Cartesian Philosophy), Principle XII, distinguished between ordinary vacua, which occur when we do not find the things we ordinarily expect to find in some container, and absolute vacua, which are places completely devoid of matter. When someone removes air from a container, something else must flow in, some exceedingly fine material which can flow through the walls of the container[4]. Insofar as

there is no evidence to the contrary, it is reasonable to assume that Spinoza's ideas on this point were the same.

Another major feature of the Cartesian physics is that atoms, i.e. indivisible bits of matter, do not exist. It is part of the concept of extension that extension is always divisible. Axiom 9 says: "All extension can be divided, at least, in thought.". A great deal hinges on the phrase "at least in thought", as I will elaborate shortly.

Although atoms as indivisible bits of matter are not part of the Cartesian physics, the system is nevertheless based on particles. To evaluate the character of the Cartesian particles and the general Cartesian cosmology, we turn to the account of the creation of the universe as given in Part Three:

> ...in the beginning, all matter of which the visible world is composed was divided by God into particles as nearly as possible equal to one another. These particles, however, from which now the heavens and the stars are composed were not spherical, for a number of spheres joined together do not fill up the space they occupy; but they, small in size, were fashioned in some other way. These particles had in them just as much motion as there is in the world today and they were all moving with an equal velocity.

Since the creation of the universe particles of all sorts of sizes and shapes developed and assumed various configurations which constitute the world we see today.

All scientific explanation is in terms of particles

in motion. To give detailed descriptions and causal explanations, a theory of the behaviour of particles is needed. This theory is stated in Proposition 14 to 37, inclusive. This theory can be divided in two parts: (a) pertaining to bodies in isolation, (b) pertaining to bodies in collision. A body in motion tends to continue in straight line motion, i.e. it will continue in a straight line with undiminished velocity unless it interacts with other bodies (see Corollary to Proposition 14, Prosition 15, 16 and 17). There is no corresponding rule or law for bodies at rest; this is important, as we shall see.

As regards bodies in collision the first rule or law is that in an impact there is no loss of motion (see Propositions 18, 20, 21, 22). Note at this point that motion is not merely velocity in the Cartesian physics, the amount of motion that a body possesses is dependent on both the size and the velocity of the body. Although this is not stated explicitly, the quantity[5] of motion of a body is actually just the product of its size and velocity. In any collision between two bodies, the total quantity if conserved.

Following the statement of this law there are given a number of propositions dealing with collisions in more detail. In Descartes's Principles of Philosophy

(paragraphs 46 to 52 inclusive) are found his well-known seven rules of motion. Spinoza states these rules with some relatively minor and not obviously significant modifications (of which I have already mentioned the sixth rule). He also adds one extra proposition to the series, ostensibly to fill a gap. These propositions are given below; for the sake of clarity, I have given them in my own words:

Proposition 24 (Rule #1): If two bodies of equal size and equal velocity collide, each will return in the opposite direction without any change of velocity.

Proposition 25 (Rule #2): If two bodies with different sizes, but equal velocities, collide, the smaller one will be reflected in the opposite direction with its original velocity, while the larger one retains both its original direction and velocity.

Proposition 26: If two bodies have both different size and velocity, but the product of velocity and size is the same for both, then upon collision both bodies will rebound with their original velocities.

Proposition 27 (Rule #3): If two bodies of equal size but with different velocities collide, the faster body will give half of its excess velocity to the slower body and they will both move on together in the direction of the faster body.

Proposition 28 (Rule #4): If a body at rest is struck by a smaller body, then, no matter how great the velocity of the smaller body, the larger body will remain at rest, while the smaller is deflected at an angle, retaining its original velocity.

Proposition 29 (Rule #5): If the body at rest is smaller than the impinging body, then no matter how slowly the impinging body moves, it will give up part of its velocity to the body at rest so that they both move on together.

Proposition 30 (Rule #6): If the body at rest is struck by a body of equal size, the first body will be impelled and the second body will be repelled.

Proposition 31 (Rule #7): If a body, A, is moving faster than, but in the same direction as another body, B, then either (a) the product of size and velocity of A is larger than the corresponding product for B, in which case A will give up part of its velocity to B and they will both move on together, or, (b) the product of size and velocity of A is smaller than that of B, in which case A will be reflected back while B moves on, each with its original velocity.

Two aspects of these seven laws of motion stand out immediately. The first is that they seem plainly contrary to experience, and they have been criticized

on this count by many. Scott[6] mentions one contemporary criticism directed at the fourth rule. It is a common experience that a very small object, such as a bullet, striking a large stationary one, say a cannonball, with high velocity, will cause some movement in the large object, contrary to the fourth rule, which states that the smaller body will bounce back, while the larger body remains at rest. An example of a later criticism is that of C. D. Broad[7] who states that

> ...some laws hold only when bodies are perfectly elastic, others only when they are perfectly inelastic and others under no conditions whatever.

Two considerations make this judgment a little misleading. First, it is true only if a certain assumption is made regarding the mass of bodies. In the Cartesian scheme, two bodies equal in volume possess an equal amount of corporeal matter, even though they may be different materials, such as brass and gold. In the Newtonian scheme, two such bodies would have different masses, even if they occupied the same amount of space: that the different conceptions of mass in the Cartesian and the Newtonian scheme make a judgment of the Cartesian system in Newtonian terms a little misleading is fairly obvious, and does not need to be spelled out. A second point overlooked by Broad is that the collisions with which the seven rules deal are collisions in isolation. Now

since the universe is a plenum, there is never actually any isolated collision, so that these laws do not apply directly to the world of experience. In the Scholium to Proposition 31 Spinoza states:

> For explaining the changes of bodies which are mutually impelled we have so far considered two bodies as though separated from all others, no account being taken of other impinging bodies.

That is, the seven laws are what we might call primary laws, and for scientific explanations we need a set of secondary laws, derived from the primary laws, which do apply to the observable phenomena. In the last six propositions of Part Two, a start is made in giving these secondary laws, but the task is not pursued to any great extent.

The second notable aspect of the seven laws is that a sharp distinction is made between bodies at rest, and bodies in motion, no matter how slowly. To given an example, let us look at Rules #4 and #7. Consider a small body, say a bullet, striking a larger object, a cannonball, at rest. Rule #4 states that the bullet will bounce back while the cannonball remains at rest. Now imagine the cannonball to move in the same direction as the bullet but with an exceedingly small velocity, such that the quantity of motion (size times velocity) of the bullet is larger than that of the cannonball. This

brings the example under the consideration of the first case of the seventh rule, which says that the cannonball and the bullet will move on together, which is radically different from the case of the cannonball at rest. What in the Newtonian system would count as an extremely small change, namely a slight change of velocity in the cannonball, which correspondingly produces a small change in the effect produced, in the Cartesian system produces a drastically different situation. Several such cases of a radical difference produced by a small change in the initial conditions, can be discovered by examining these seven rules. The example I have considered is of particular significance in that it makes clear that the state of rest does have a special status in the Cartesian scheme. Also what it brings out clearly is an important difference between the Newtonian and Cartesian schemes with respect to moving frames of reference. To give a homely example, let us imagine ourselves sitting in a railroad car and observing the collisions of bodies. In the Newtonian case it would be impossible to tell from the observed collisions of bodies whether the railroad car were moving or not. In the Cartesian scheme, with its special laws for bodies at rest, we would be able to determine whether the railroad car was moving or not. This is an important bearing on the question of the

"relativity" of the Cartesian space, a topic I will return to shortly.

The reasoning by which these rules of motion are established is interesting and worth exploring. Each proposition is argued separately, but the whole set of rules involves basically four principles:

(a) The principle of conservation of motion (as I call it) is the basic rule that applies to all cases of collision between two bodies. However, while none of the rules violates this principle, not all rules are specific enough to exclude the possibility of violation. When they are examined, the rules can be seen to fall into two classes. In the one class, which includes Rules #1, 2, 3, 4 and part (b) of #7, and also Proposition 26, the final velocities are definitely specified, while the other class, which consists of Rules #5, 6 and 7(a), the resultant velocities are left undetermined. In the former case, given the sizes and initial velocities, it is possible to calculate the final velocities, while in the latter this is not possible on the basis of the rules. The latter rules, therefore, are incomplete in that they do not <u>guarantee</u> the conservation of motion in the universe. This is significant because the constancy of the universe is an important issue in both Descartes's and Spinoza's philosophies, and it indicates that the

physics of the Principles should not be regarded as a closed, finished, system, but rather as a prototype or blueprint for a fully developed physics.

The set of rules is also incomplete in another way. All the possible combinations of sizes and velocities are covered with one exception, namely the case in which two bodies with different size and velocity meet each other head on. What is missing is a rule like #7, but for bodies moving in opposite directions. This omission may be significant in various ways, but for lack of clues the exploration of its meaning will necessarily be highly speculative; since it does not seem to be pertinent to the main topic of this thesis I will forego the discussion of this point. For my purpose all that is relevant is that the laws of motion are not developed to the full extent which is possible within the theoretical framework of the Principles.

(b) The contest-of-strength principle (as I call it) is one that applies to all rules. It states that in any collision the stronger body shall suffer the least possible change, and the weaker body undergoes as much as is required; relative strength is determined differently in cases where body bodies are in motion, and those cases where one body is at rest. In the former case the stronger body is the one with the larger quantity of

motion, while in the latter case size alone determines superiority. The crucial axiom in connection with this principle is Axiom 20: "Variation in any object proceeds from a stronger force.". It is not explained anywhere why strength should be determined in the way I have described. It just seems to be taken for granted.

The fact that strength is determined differently in the case of rest and in the case of motion is rather important, in connection with the concept of quantity of rest, and I will return to it shortly.

(c) The principle of symmetry (as I call it) applies to Rules #1 and #6 and to Proposition 26. It says that when two bodies are equal in strength, the result of a collision will be symmetrical with respect to those bodies. What is interesting about this principle is that it bears a kinship to Leibniz's law of sufficient reason. In the case of the first rule, there is just no conceivable reason why what happens to one body should be any different from what happens to the other; ergo, the results must be the same for those bodies. The principle does not apply so clearly to Proposition 26, where the two bodies are not completely symmetrical and only equal in one respect, namely the quantity of motion. A similar case is the sixth rule, where the bodies are equal in size, but differ in velocity. For a more

detailed discussion of the principle of symmetry as it applies to the sixth law, see Appendix C.

(d) The principle of economy (as I call it) states that the changes due to a collision shall be the minimum possible. This principle is interesting in that it has the character of a principle of least action. Its application in the proofs is obscure and because of this, and also because it has no relevance to Spinoza's later writings, I will not delve into it. The only directly relevant aspect of this principle is in the way change is calculated; for the purpose of deciding how much change a particular collision involves, change in motion and change in direction are counted quite separately. For example, in the case of Rule #1, each body undergoes no change in velocity, only in direction. How changes in direction are to weigh against changes in velocity is uncertain, but the important point is that motion in the Cartesian physics is not a vector quantity as are velocity and momentum in the Newtonian physics. For example, let us consider a body whose velocity is 10 units and let us say it suddenly reverses its direction of motion completely. In the Newtonian system the body has undergone a change of 20 units, while in the Cartesian system there has been only a change of direction. This example should serve to emphasize the rather different character of motion

in the Cartesian system and the difficulty of making judgments of that system in Newtonian terms.

I have not taken the time or space to examine in detail the arguments for the rules of motion, and I do not think this is necessary. On the whole the system is carefully worked out and there are no obvious flaws in the logic by which they are derived, although there are several obscurities, especially with regard to the principle of symmetry and the notion of quantity of rest. As I have tried to show, the obvious implausibility of the laws of motion is not so obvious when their derivation and application is examined more closely. Despite the obscurities, anyone who reads the Principles attentively will see that the theory presented there represents an attempt to come to grips with the basic physical concepts; one can sense a groping towards a fully developed mathematical science of mechanics, an effort to formalize the concepts of mass, velocity, momentum, inertia, force, concepts which were fully formalized by Isaac Newton. In particular I want to mention the inertia of bodies at rest, which is connected with the notion of quantity of rest. To explore this notion further we will first consider the more general question of the definition of motion in the Cartesian system. For that we will turn to Definition 8 which reads as follows:

> Local motion is the transference of a particle of matter or of a body from the vicinity of other contiguous bodies considered as in a stated of rest, to the vicinity of others.

Together with this definition there is a long discussion consisting of five points; I have paraphrased and abbreviated these:

1. A particle of matter is to be understood as all that which is transferred at the same time, although it may itself be composed of many parts.

2. Transference is not to be confused with force or action which transfers. This force or action, as is generally believed, is required only for motion, and not for rest, which is plainly wrong. That it requires just as much force to put a body into motion as it does to bring it to rest, is self-evident, and it is also proved by experience; a ship requires about the same force to be put in motion as it requires to be stopped, and this would be exactly the same if we ignored the weight and viscosity of the water.

3. Transference is not made from one place to another, but rather from the contiguity of one body to the contiguity of another. Place is not something that belongs to an object, but it depends on our thought.

4. When we consider two bodies, it is apparent that the motion of one with respect to the other is

reciprocal. When we push a boat out of the sand we push the boat and the sand with equal force. The action and the reaction are equal. So the boat moves with respect to the sand as much as the sand moves with respect to the boat. But the latter phrase is too much at variance with the common way of speaking, which is to attribute only to the boat a motion.

5. Every body has its own one proper motion, because motion is defined as transference from bodies at rest.

As regards the relativity of motion there seems to be a manifest contradiction between points 4 and 5. Point 4 considered by itself seems to imply that motion is a relation between two objects, whereas point 5 states bluntly that each body has its one proper motion. From the sharp distinction that is made by the laws of motion between bodies at rest and those in motion, it is clear that point 5 means what it says. Both relative and absolute motion play a part in the Cartesian scheme. A definition of absolute motion would read: "motion is transference from bodies at rest" while the definition of relative motion would read: "motion is transference from bodies <u>considered</u> at rest".

This, however, still leaves a question about the definition of motion in terms of rest: how is rest defined?

If rest were defined in terms of motion we would unavoidably run into a circularity. As a matter of fact rest is not defined at all, except indirectly. This brings us back to the notion of rest as a quantity (see page 29). This notion is that there is a perfect symmetry between motion and rest; the faster a body moves the more it partakes of motion and the greater its quantity of motion is; the slower a body moves, the more it partakes of rest, and the greater is its quantity of rest. Proposition 18, which states that if, in a collision, one body acquires no motion from the collision then the other party to the collision loses no motion, has the following demonstration:

> If you deny it, let it be supposed that A has lost some of its motion but has not transferred it to another body, as, for example B. If this happens there will be less motion in Nature than before which is absurd. (see Prop. 13). The demonstration in respect to rest in B is the same. Therefore if no motion is transferred B will be in the same state of rest and A will retain the same amount of motion. Q.E.D.

The important phrase is "the demonstration in respect to the rest in B is the same"; here is one example of an attempt to formulate rest as the opposite of motion. The Corollary to Proposition 19 states: "Hence it follows that motion is not the opposite of motion" Indirectly this implies that rest is the opposite of motion, the general idea being that a loss of motion is a gain of rest, and a gain in motion is a loss of

rest, and vice versa. In the demonstration to Proposition 22 there occurs another significant passage:

> Therefore those moving more swiftly have more motion (per Def. 8). In bodies at rest by force of resistance we understand the quantity of rest. From which follow: Corollary I. The more slowly bodies move, the more they partake of rest, for bodies having a greater velocity meeting those which have less force, resist more and are not separated so far from bodies immediately contiguous to them.

The important sentence here is "the more slowly bodies move, the more they partake of rest". The question is, how is quantity of rest formulated, and how is it used? Before we deal with this question, we might first ask another question: why is rest as a quantity needed, what does it explain? The answer to the latter question can be found in Point 2 of Definition 8. The key sentence there is: "This force or action, as is generally believed, is required only for motion, and not for rest, which is plainly wrong.". The reasoning involved is something like the following: since just as much force is required to speed things up as is required to slow them down, motion and rest, speed and slowness, are symmetrical opposites. Therefore, the faster things move, the more they partake of motion, the greater their quantity of motion; conversely, the slower things move, the more they partake of rest, the greater their quantity of rest. Just as the force of impulse of motion depends on quantity of motion,

so the force of resistance of rest depends on the quantity of rest.

What is involved here is the concept of inertia for bodies at rest. In the Newtonian system there are two separate laws in the principle of inertia: (a) bodies in motion stay in motion, (b) bodies at rest stay at rest. As I have already mentioned (see page 21), in the Cartesian system there is a clear statement of only the second part of this principle. The question of why there is no statement for the first part is connected with this notion of rest not as a state of zero motion, but as something opposed to motion. It is not only difficult to state a principle of inertia for rest, defined in this manner, it is also difficult to give a mathematical formulation of the notion of quantity of rest: the quantity of motion is the product of size and velocity, but how shall quantity of rest be formulated? If we consider how the principle of contest-of-strength is applied to the laws of motion, then we will see that the effective, or actual formulation of quantity of rest used is the following: the quantity of rest of a body at rest is proportional to the size of the body - the quantity of rest for bodies in motion is zero. In effect then, the notion of rest as slowness, as relative absence of motion, apparently is not even applied in the rules of motion.

If it were applied, then it is very difficult to see how. On this point there is somewhat of an inconsistency in the physics of the Principles. This notion of quantity of rest, and rest as the opposite of motion, is rather hard to grasp, and the effort to reconstruct the thought processes involved is necessarily somewhat speculative in character. What does stand out clearly is that in the Principles there is an effort to come to grips with the concept of inertial mass, and that this effort leads to a concept of rest as something opposed to, but symmetrical with motion. This point is crucial for understanding what Spinoza says in the Ethics about motion.

Besides the difficulties associated with formulating motion, a number of other problems arise from the definition of corporeal matter as extension. These problems are of particular concern to the physics of the Ethics, and are, in my opinion, crucial to the understanding of what Spinoza says about physical substance in his other writings.

Physical substance and extension are one and the same thing, in the physics of the Principles; let us explore the consequences of this fundamental axiom, assumption, postulate or hypothesis, whatever one wishes to call it. The definition of extension is Definition 1:

Extension is that which consists of three dimensions.

> We do not understand by the term the act of extending or anything else distinct from quantity.

Extension is perfectly homogeneous, one part of it is no different from any other; it is infinitely divisible: any part of it can always be seen as consisting of yet smaller parts. It is not only infinitely divisible but also infinite in extent; it makes no sense to think of anything "outside" of extension (see Axiom 10), nor for that matter something "inside" extension and yet not part of it, such as the vacuum (see Proposition 3).

Extension by itself is not sufficient to explain the variety of observed objects and phenomena; for that motion-and-rest is needed. Motion-and-rest "breaks up" extension into a myriad fragments which together constitute the world of variety and change. It is this picture of the universe to which Descartes's famous identification of physics with geometry is applicable. Descartes said: "Qu'on me donne l'étendue et le mouvement, et je vais refaire le monde", and, "L'universe entier est un machine ou tout se fait par figure et mouvement.".

One conceptual difficulty inherent in this picture concerns the separate existence of particles. If we imagine a composite body consisting of a number of particles at rest with respect to each other, the question

that immediately arises is, in what sense is such a body composite at all? And if it is composite, why must it consist of a particular set of particles, since it can also be conceived as consisting of a quite different set of particles. There is a profound difficulty in the phrase occurring in Axiom 9: "All extension can be divided, at least, in thought.". It is difficult to conceive how the existence of separate particles is compatible with extension as geometrical space.

This difficulty does not, at first sight, occur in connection with particles which are in motion with respect to each other. Axiom 16 says: "Matter which is moved in different ways has at least as many divided parts as there were degrees of swiftness observed at any given time.". If the "at least" is ignored or deleted then we seem to have an acceptable pragmatic definition of a particle. But the same difficulty crops up again. Since all particles are at all times in contact with their neighbours, it is clear that any relative motion between adjacent particles must always be sliding motion. Now, if we imagine two particles sliding past each other, we can ask the same question as above, namely, at the contracting surfaces what precisely is it that marks the boundaries between the two particles; and if there is nothing, then the two particles are in effect one larger

one which is changing its shape, and it follows therefore all the particles in the universe are inseparably fused together, and it is impossible for motion to "crack" extension.

This kind of conceptual difficulty is admittedly an intuitive one, but it is the greatest importance for understanding many of Spinoza's utterances, so I will try to explain it a little further. The space = body postulate (as I call it) offers no conceptual difficulties as long as one has in mind the following picture: the universe is space filled with some sort of transparent substance whose only physical property is that it is extended. Motion is brought into this glassy material, and breaks it up into fragments which from then on never cease moving about. This picture is easily understood and it is to this picture that the word "plenum", a space full of body, is appropriately applied. However, the Cartesian universe does not actually fit the plenum picture of the universe, because a different claim is made, namely not that space is filled with body, but rather that space and body are one and the same. That this is so is clear, amongst other things, from what the Principles says about the vacuum. It says that the very idea of a vacuum is self-contradictory, whereas in the plenum universe the existence of the vacuum is a contingent

matter: it is quite possible to think of a bit of space not containing any corporeal matter.

There are several difficulties inherent in the Cartesian identification of corporeal matter with extension. First, it leads one to speaking, in effect, of a region of space moving in the place of some other region of space, which is quite odd. Another is that it gives the eight laws of motion a very peculiar status: to state, as a hypothesis, that two bodies collide in isolation, is to begin an argument with the logically impossible premiss: anything at all follows from a contradiction. From the point of view of this thesis, the above mentioned problems are not important, since nowhere does Spinoza devote any attention to them, but there is a third kind of difficulty which is extremely significant, and this is the difficulty of reconciling the separate existence of particles with the continuous character of extension.

How seriously the identification of matter and geometrical space is taken can be seen from Axiom 9:

> All extension can be divided, at least, in thought. Concerning the truth of this axiom no one can doubt who has learned even the lements of mathematics. For the space between a given circle and its tangent can always be divided by an infinite number of greater circles. Which is also true as regards the asymptote of the hyperbole.

The crucial point is that the <u>Principles</u>

recognizes two types of division in extension:

(a) division in thought; geometrical extension is perfectly continuous: we can always think of a particular shape as being split into two parts by a plane, a plane figure being split up by a line, a line divided by a point; anywhere in the three dimensional continuum we can mentally construct a shape, and on paper we can represent this shape by pencil lines which represent geometrical surfaces or lines. This is the force of the phrase "in thought".

(b) actual division; through the agency of God the geometrical continuum has actually come to be divided in parts, whose motions and configurations account for the daily physical events in the world of experience.

Without further discussion I think one can see how the Cartesian physics is caught between two contradictory desiderata. On the one hand it wants to retain the purity of geometrical extension which is continuous and can be thought of as consisting of parts without destroying its essential unity, and at the same time it wants to import into this realm the actuality of motion, which can account for the world of change[8].

It should be stressed, at this point, that I do not presume to have given the difficult issue of how to reconcile the indivisibility of the continuum with

the world of particulars anything like a full treatment; my effort has been directed toward showing that this kind of conceptual problem does arise from the space = body postulate. Later I intend to show that Spinoza did indeed have an intense concern for this type of problem, and that is why I have introduced this topic in the Principles.

Looking at Part Two of the Principles as a whole, it is plain that as a physical theory it is a failure. There are profound contradictions in the basic premisses, and there are flaws in the rules of motion, although these flaws are not as obvious as some have thought. But, in a way, it is a magnificent failure: there is an attempt, in one short work, to lay, once and for all, the foundations for all physical science. Not only is the scope ambitious, but the method is appealing. By starting from what were thought to be eminently clear concepts, extension and motion as the sole primary qualities of matter, and proceeding by a careful deductive method, the truths arrived at would have a mathematical certainty about them. Besides, it held out the promise of explaining a great number of physical phenomena without having to resort to such mysteries as gravity, a force that acts at a distance, the vacuum, something that is and yet is nothing, atoms, which are extended and are

at the same time indivisible. All this makes the Principles an interesting document in the history of science, and a worthwhile subject for study in its own right.

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[1]See, for instance, the Treatise on the Rainbow.

[2]On what philosophical grounds the identification of physical substance with extension is made, and correspondingly what logical status this identification has in the system of the Principles, is a question I do not deal with, because, for one thing, it would involve us too far in Descartes's metaphysical theories.

[3]Throughout this thesis I use the term "Newtonian" to denote what is now labeled "classical mechanics", without making any implications about Isaac Newton's thought processes.

[4]For comments on Boyle's experiments to test the Plenist hypothesis, see Conant, pages 34-38.

[5]Throughout the Principles, "motion" and "quantity of motion" are synonymous terms, so that the word "quantity" is generally superfluous.

[6]Scott, page 163.

[7]Broad, page 165.

[8]It might also be noted that by the introduction the actual division into the geometrical continuum, there has also been introduced a contingent factor into the subject of geometry, so that the truths about the physical world do not possess the same apodeictic character that we attribute to mathematical truths. It seems to me this has some bearing on Spinoza's doctrine of necessity, but I would like to avoid that subject if I can.

CHAPTER IV

THE PHYSICS OF THE ETHICS

The main body of Spinoza's physics in the Ethics is found in the Scholium after Proposition 13 of Part Two. This proposition reads as follows: "The object of the idea constituting the human mind is a body, or a certain mode of extension actually existing and nothing else.". It is interesting to note how the physical theory is hidden, we might almost say, in a scholium on a proposition which deals with the connection of body and mind. This is indicative of how minor a role physics as such plays in Spinoza's grand scheme; he mentions the subject only in order to reinforce certain points of metaphysical doctrine. Because the purposes for which Spinoza introduces his physical theory are a good deal clearer than the theory itself, we might well begin by outlining these purposes.

One of these purposes is to explain the interconnection between body and mind, to make sense of the notion that the mind is the idea of the body. The Scholium starts out as follows:

> Hence we see not only that the human mind is united to the body, but also what is to be understood by the union of mind and body. But no one can understand it adequately or distinctly without knowing adequately beforehand the nature of our body; for

> those things which we have proved hitherto are altogether general, nor do they refer more to man than to other individuals, all of which are animate, although in different degrees.

Spinoza explains the special status of the human mind in terms of the organized complexity of the human body; although all bodies are animated, there are degrees of animation, corresponding to degrees of organized complexity. Sticks and stones, which are at the bottom of the scale, have a very low level of structural integrity; human beings, at the top of the scale, have a body which is highly integrated and hence their minds are greatly superior to the "minds" of sticks and stones.

Besides explaining how some bodies can be said to be animated to a higher degree than others, Spinoza's physical theory serves another purpose, namely how we have knowledge of the outside world. From the fact that a mind is the idea of a body, it would seem to follow that minds can only know the bodies with which they are associated. Spinoza's solution to this is to show that bodies are affected by bodies external to them. How this is worked out we can see from Postulate 5:

> When a fluid part of the human body is determined by an external body, so that it often strikes upon another which is soft, the fluid part changes the plane of the soft part, and leaves upon it, as it were some traces of the impelling external body.

We find here a sort of causal theory of perception:

we perceive the external world because it affects our bodies. This theory of interaction amongst bodies is the apparent purpose for the introduction of the definition of hardness, softness and fluidity, and it explains the presence of this bit of physical theory in the Ethics.

A third purpose of the Ethics is to provide a way of explaining how the universe as a whole is changeless, even though all sorts of changes take place within it. To see how this is done, we need to look a little closer at Spinoza's theory of individuals. Before we do this, however, it might be better, first, to discuss some of the more general features of the physics of the Ethics.

One major, and deplorable, feature of the physics of the Ethics is its brevity. At first sight the impression is that it is just a bit of incidental material stuck away in a corner; for example the fourth axiom (see page 49) does not seem to fit in with what Spinoza says before or after. The theory presented seems so sketchy that it hardly deserves the title "physics". Yet when we look a little closer, we will find that it all hangs together, and furthermore, that almost all the basic elements that are necessary to lay down the foundations of physical science are there.

I will take advantage of the brevity of the

theory presented by stating all the axioms, definitions, and lemmas of the Scholium to Proposition 13, Part Two, in the order in which they occur. This by itself will give a good idea of the form and style of the physics of the Ethics. Besides, I shall be referring to almost all of these sooner or later, so that it is convenient to state them here and now. I have omitted the six postulates which come as a body at the end. These postulates are clear and uncontroversial, so that they can safely be paraphrased. What they state is that human bodies are composite to a high degree, that parts of the human body are either soft, hard or fluid, that human bodies are affected by and can affect the external world in many ways, that they regenerate themselves continuously from outside material, and that external bodies at times leave lasting effects on the human body.

Axiom 1: All bodies are either in a state of motion or rest.

Axiom 2: Every body moves, sometimes slowly, sometimes quickly.

Lemma 1: Bodies are distinguished from one another in respect of motion and rest, quickness and slowness, and not in respect of substance.

Lemma 2: All bodies agree in some respects.

Lemma 3: A body in motion or at rest must be determined to motion or rest by another body, which was also determined to motion and rest by another, and that in its turn by another, and so on ad infinitum.

Corollary to Lemma 3: Hence it follows that a body in motion will continue in motion until it be determined to a state of rest by another body, and that a body at rest will continue at rest until it be determined to a state of motion by another body.

Axiom 3:[1] All the modes by which one body is affected by another follow from the nature of the body affected, and at the same time from the nature of the affecting body, so that one and the same body may be moved in different ways according to the diversity of the nature of the moving bodies, and, on the other hand, different bodies may be moved in different ways by one and the same body.

Axiom 4: When a body in motion strikes against another which is at rest and immovable, it is reflected in order that it may continue its motion, and the angle of the line of reflected motion with the plane of the body at rest against which it struck will be equal to the angle which the line of motion of incidence makes with the same plane.

Definition: When a number of bodies of the same or different magnitude are pressed together by others, so that they lie one upon the other, or if they are in motion with the same or different degrees of speed, so that they communicate their motion to one another in a certain fixed proportion, these bodies are said to be mutually united, and taken altogether they are said to compose one body or individual, which is distinguished from other bodies by this union of bodies.

Axiom 5: Whether it is easy or difficult to force the parts composing an individual to change their situation, and consequently whether it is easy or difficult for the individual to change its shape, depends upon whether the parts of the individual or compound body lie with less or whether with greater surfaces upon one another. Hence bodies whose parts lie upon each other with greater surfaces I will call hard; those soft, whose parts lie on one another with smaller surfaces; and those fluid, whose parts move amongst each other.

Lemma 4: If a certain number of bodies be separated from the body or individual which is composed of a number of bodies, and if their place be supplied by the same number of other bodies of the same nature, the individual will retain the nature which it had before

without any change of form.

Lemma 5: If the parts composing an individual become greater or less proportionally, so that they preserve to one another the same kind of motion and rest, the individual will also retain the nature which it had before without any change of form.

Lemma 6: If any number of bodies composing an individual are compelled to divert into one direction the motion they previously had in another, but are nevertheless able to continue and reciprocally communicate their motions in the same manner as before, the individual will then retain its nature without any change of form.

Lemma 7: The individual thus composed will, moreoever, retain its nature whether it move as a whole or be at rest, or whether it move in this or that direction, provided that each part retain its motion and communicates it as before to the rest.

The outstanding difference between the physics of the Ethics and that of the Principles is that the former contains a much more sophisticated and powerful theory of composite body, namely the theory of individuals. There is no evidence that this theory is not completely original with Spinoza; at least there is no hint of it in the Principles, so that this part of the physical theory can properly be labelled "Spinoza's physics".

Although the theory of individuals has far reaching and complex ramifications, it is rather simple in outline: the universe is a hierarchy of different kinds of individuals; at the bottom of the scale there are the individuals of the simplest kind, whose component parts are the simplest bodies, the corpora simplicissima;

these lowest levels combine to form individuals of the second order, and these again to form individuals of the third order, and so on. At the highest level there is only one individual, the universe itself.

The picture of the universe as a hierarchy of composite bodies with the universe at the top, and the particles at the bottom, is not hard to understand and is on the face of it quite appealing. What is more difficult to understand is how a number of elements combine to form a larger unit, i.e. what binds the elements together and in what way can a number of simpler units be part of a more complex unit, what does the structural integrity of a particular individual consist of. Answers to these questions are not readily available because of the conciseness and almost enigmatic character of the physics of the Ethics. That somehow the concept of organized complexity involves the motions of particles is fairly clear from the Definition, but what the properties of these particles or simplest bodies are, and what the character of motion is, is just as difficult to determine as the nature of organized complexity of the individuals, and obviously these questions are interrelated. In the next two chapters I will examine these questions more closely.

At this point it might be useful to compare

the physics of the Ethics with that of the Principles, for the purpose of considering some of the obvious differences and similarities. Outside of, perhaps, the theory of individuals, there seems to be little in the physics of the Ethics that would mark it as something radically different from the physics of the Principles. For instance, the fourth axiom is quite similar to the fourth rule of motion (Proposition 28) of the Principles and the former might well at first sight be regarded as a reformulation of the latter. It is true that there are no corresponding axioms for the other rules of motion, but this has a ready explanation in that, after all, the Ethics is not primarily a work on physical science, so that other laws of motion would not be pertinent to its purpose. Why Spinoza includes this law and not others may be quite insignificant.

The physical theory of these two works is similar in other respects as well. For instance, in both cases the fundamental elements of scientific explanation are motion and particles. The basic method or procedure is, superficially at least, the same. Not a single reference is made in the physics of the Ethics to anything like experimental evidence or observational data[2]. There is no mention of action at a distance; the fourth axiom, the only item that deals with the

interaction of bodies, suggests that bodies can interact by contact alone, just as in the Principles. On the question of the vacuum there seems to be agreement as well; in the Scholium to Proposition 15, Part One of the Ethics, Spinoza states:

> Everyone who knows that clear reason is infallible ought to admit this, and especially those who deny that the vacuum can exist.

All in all, enough similarities exist to justify the tentative assumption that Spinoza's ideas about the structure of the physical universe are well represented by Part Two of the Principles. What might argue against this assumption is that on several major points of philosophical doctrine Spinoza's position is antithetical to that of Descartes; some of these will be discussed later. Also, there is one instance of Spinoza's outrightly condemning Descartes's "principles of natural things" in no uncertain terms (letter to Tschirnhaus, May 1676); I will return to this point in a later chapter.

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[1]Spinoza labels this axiom and the following two axioms as Axiom 1, 2 and 3 respectively, but for convenience sake I will call these Axiom 3, 4 and 5 respectively.

[2]In the Principles there is a reference here and there to practical cases, but these are mainly used as examples to strengthen the argument.

CHAPTER V

THE THEORY OF INDIVIDUALS

The theory of individuals has obviously a very important role to play in Spinoza's grand scheme; it is not merely a theory of composite body but also, a way of explaining the interaction of mind and body. From the point of view of this thesis the discussion of this theory will of necessity be quite limited; it will be limited to considering the theory as a physical theory, namely a theory of composite body.

Whatever else is obscure about the theory of individuals, this much is certain: Spinoza distinguishes clearly between two kinds of bodies, the simplest bodies and the individuals. The first four axioms and the first three lemmas apply specifically to the corpora simplicissima (I will take the liberty of abbreviating it as corp. simp.). This is evident from the statement immediately following Axiom 4: "Thus much for simplest bodies which are distinguished from one another by motion and rest, speed and slowness alone; let us now advance to composite bodies.". He then proceeds to give the definition of an individual.

The first question we might ask is how the constituent parts of any particular individual are bound

together, in what way they combine to form a larger unit. Looking at the definition, we see that there are basically two ways in which this is done: (a) a number of bodies are at rest with respect to each other, or, (b) a number of bodies exhibit certain regularities in their motions with respect to each other. Case (a) can be understood by thinking of a house built out of bricks while (b) is perhaps represented by a wheel rotating about a fixed axle, or a watch, whose parts exhibit certain definite relations of motion. If we consider relative rest as a special kind of regularity, then (a) is actually only a special case of (b): we can say then that the "structural" integrity of an individual lies simply in the regularity of the motions of the parts of the individual.

One has to be somewhat careful in the use of these examples. Spinoza gives no simple examples; the only example he does give is the human body, which, as we can see from Postulate 1, is highly complex in that the constituent parts of human bodies are themselves composite to a high degree. Hence we are somewhat at a loss when we try to imagine how all the details are supposed to be worked out, nor is there any evidence that Spinoza had worked these details out. So the talk about watches, wheels or houses is somewhat speculative in nature.

What is fairly clear, however, is the concept of an individual as something more than the sum of its parts. Just as in the case with the modern notion of the atom, which is more than a mere collection of protons, neutrons and electrons, the individual is more than a collection of parts, it is a "union of bodies", an organization of parts. Spinoza conceives of the universe as a whole as a super individual (see Scholium to Lemma 7) and this indicates a cosmology somewhat different from that of the Cartesian physics. The picture of the Cartesian universe is that of a giant conglomeration of all sorts of particles in motion with no essential unifying factor[1]. In the Cartesian physics a composite body has structure only insofar as the parts of the body happen to be close together for a certain period of time, while in the Ethics a composite body has definite organized complexity. On the other hand, the Ethics and the Principles have in common that in neither are there mentioned any attractive forces, or any physical entity that binds particles together. In the definition the phrase "pressed together" occurs, and this is the only phrase that suggests force in any form or way. This phrase is well in accord with the picture of the universe as presented in the Principles, namely as a plenum, a space completely filled with particles, and where the motion

of any particle must involve the motions of one or more of its neighbours.

This notion of organized complexity, that the composite body is more than the sum of its parts, is very important to Spinoza's metaphysical scheme; the universe is the body of God, and hence in some way it must be a unit, an organized whole and somehow it must be changeless. That the universe as a whole, being an individual, is a unit, is not so problematic, but in what way the universe is changeless is more difficult to understand. This is but part of a more general problem, namely in what way are individuals in general said to be undergoing change, what constitutes a change in an individual.

Lemmas 4, 5, 6, and 7 tell us what does <u>not</u> constitute change in an individual: (1) if certain parts of an individual are replaced by others of the same nature, (2) if all the parts of an individual become proportionately larger or smaller, (3) if some parts of an individual change the direction of their motion but somehow preserve their relation with other parts, (4) if the individual as a whole comes to rest, then there is implied no change in the individual as a whole. What Spinoza has in mind with these lemmas can be seen more clearly by considering the six postulates,

which refer specifically to human bodies: (1) human bodies stay the same even though new material is ingested and old material is excreted; (2) human bodies retain much the same shape and constitution even though they increase several fold in size over the period of a lifetime; (3) human bodies have a considerable amount of freedom of movement in the individual members, without this constituting an essential change of the individual; (4) human bodies retain their identity regardless of whether they move around or are at rest.

The two important differences between human bodies as individuals and the universe as an individual, is that human bodies have neighbours, so to speak, and that human bodies are constantly subject to change, while the universe, by definition, is alone and is changeless. In the Scholium to Lemma 7, Spinoza states:

> Thus, if we advance ad infinitum, we may easily conceive the whole of nature to be one individual, whose parts, that is to say, all bodies, differ in infinite ways without any change in the whole individual.

Although it is not specifically stated, the proof of the changelessness of the universe depends on the following proposition: any change in an individual must come from outside the individual; there is no spontaneous change. It is an essential part of Spinoza's scheme that all bodies being finite and determinate,

have the cause of their existence and activity in other finite and determinate entities (see Proposition 25, Part One). In other words, to explain what happens to one body, we must always look for its interactions with other bodies. Now, for simplest bodies, how this works out is clearly explained in the physics of the Ethics. Simplest bodies have only one property that can change, namely their motion. A change from motion to rest or vice - versa is brought about only by interaction, i.e. collision, with other bodies, so that in order to explain why a particular simple body has a certain state of motion or rest, we have to refer to a history of collisions. But the case with individuals is obviously different, because besides the motion they possess as a whole, there is another property that individuals possess, namely their internal constitution. It is the regularity of the motions of the parts that constitutes the form or nature of an individual, to use Spinoza's terminology. This implies that the individual is rather a different sort of entity from the corp. simp. The individual is said to change only insofar as its internal constitution changes, while the corp. simp. change only with respect to motion and rest.

The point in all this is that Spinoza does not show in any way why individuals do not change unless

they interact with other individuals. On the basis of what he says about the corp. simp., it is quite conceivable that individuals are undergoing continuous internal change owing to the collisions of the parts, without interaction amongst individuals. But this depends on what is to count as change in an individual. One possibility is that an individual is unchanged as long as the total motion of the parts of the individual remains constant. There is evidence that Spinoza did have something like this in mind. In the letter to Oldenburg, November 1665, Spinoza discusses at length on the relation of the parts of nature to the whole of nature. He says:

> Now, all the bodies of nature can and should be conceived in the same way as we have here conceived the blood: for all bodies are surrounded by others, and are mutually determined to exist in a definite and determinate manner, while there is preserved in all together, that is, in the whole universe, the same proportion of motion and rest.

This quotation would indicate that for Spinoza the changelessness of the universe consists solely in the fact that the total quantity of motion in the universe is constant, and by implication, that each individual is changed only insofar as the sum total of the motions of parts is changed. This interpretation has the definite advantage that it makes for consistency: as long as we can show that motion is preserved in individual collisions,

then it follows that the total quantity of motion of an individual will remain constant as long as the individual does not interact with other bodies, and of course, it also follows that the total quantity of motion in the universe is constant.

On the other hand, it also would seem to follow that two individuals are the same, just in case the total quantity of motion in each is the same, and this leads to strange consequences. A tree would be the identical individual as an elephant, as long as the total quantity of motion of a tree and an elephant are the same. All watches in the world would be identical provided that the sum of the motions of the parts of each watch would be the same.

It is evident from the definition and the last four lemmas that the form and nature of an individual is more than the total sum of the motions of the parts; it has to do with certain regularities of the motions of the parts, a definite internal structure. What binds the parts of an individual together is more than the mere fact that over a given period of time the total sum of their motions is relatively constant. In some way there is organized complexity, and in some way the universe is a structured whole.

From the point of view of this thesis the

following question about Spinoza's theory of individuals is crucial: does the theory of individuals indicate a physical theory that is significantly different from the physics of the Principles? My claim is that it does not. The theory is essentially an extension of the Cartesian physics, and stems from an effort on Spinoza's part to remedy a defect of the Cartesian physics. The defect of the Cartesian physics is that the Cartesian universe is essentially an unorganized conglomeration, a mad milling about of a large number of particles; in short, it is chaotic. For Descartes's metaphysics this was no obstacle, but for Spinoza's scheme the Cartesian cosmos is unsatisfactory in at least two ways:

(a) the universe is the body of God and to see the body of God as a loose conglomeration of particles, is absurd, or at least repugnant.

(b) the human mind is the idea of the human body, and superior minds must "belong" to superior bodies; hence there must be varying degrees of animation with corresponding varying degrees of organized complexity.

What is seriously lacking in the Cartesian physics, from Spinoza's point of view, is a theory of composite body. In the Cartesian physics a composite body is basically a number of particles at rest with respect to each other and "pressed together" in the

phraseology of the definition. This implies that a human body and a stone are not very much different. The first half of the definition (see case (a) on page 55) is not adequate. There obviously are composite bodies, such as a watch, or a human body, whose parts are in motion relative to each other, and yet have a definite structure which remains relatively stable over a given period of time. Hence Spinoza's definition can be taken as an extrapolation or an extension of the Cartesian theory of composite body.

All this leaves a number of questions unanswered; for instance, precisely what are these regularities of motion, and what is to count as change in an individual; in what sense is the universe changeless? No ready answers are to be found to these questions, and it is doubtful that Spinoza had worked out the full implications of his theory. In his own words, at the end of the Scholium to Lemma 7:

> If it had been my object to consider specially the question of a body, I should have had to explain and demonstrate these things more fully. But, as I have already said, I have another end in view, and I have noticed them only because I can easily deduce from them those things which I have proposed to demonstrate.

On the whole, it can be said that Spinoza's purposes for introducing the theory of individuals are a good deal clearer than the theory itself; hence

there are a certain number of items on which enlightenment is simply not to be had. The major point is that the theory of individuals does not necessarily mean a system radically different from that of the Principles, but on the contrary, it can be seen as an extension of the Cartesian physics, an added element to fill a certain gap, or a slight modification to make it consistent with the central points of Spinozistic dogma.

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[1]Note that I am using the word "Cartesian" in the way I have defined it in Chapter III.

CHAPTER VI

MOTION IN SPINOZA'S PHYSICS

Although both the Principles and the Ethics are written in the geometrical form, the former is much more easily understood than the latter. It seems almost as if the physics of the Ethics is a condensation of the Principles, and the Principles is already a work of great conciseness. In the Ethics Spinoza does not bother to discuss his theory in detail or elucidate it by means of examples. Furthermore, and this is especially true on the subject of motion, his terminology is unfamiliar and almost incomprehensible at times. My main task, therefore, is to try to make some sense out of the statements dealing with motion, and to try to trace a connection between them and corresponding parts of the Principles.

Whatever else is unclear, it is clear that the laws or principles of motion fall into two categories: (a) those governing bodies considered in isolation, and, (b) those governing the interaction of bodies. Category (a) is filled by the Corollary to Lemma 3 (see page 49) while the fourth axiom (see page 49) is the sole representative of category (b). The Corollary to Lemma 3 is Spinoza's principle of inertia: bodies in motion tend to remain in motion, while bodies at rest tend to remain

in that state. This principle is not stated as a basic postulate about nature, but rather it is dependent on statements established before. The preceeding lemma states that a change from motion to rest or vice versa can come only from interaction with other bodies; this lemma in turn depends on Proposition 28 of Part One, which states that the cause of the activity and existence of one particular finite thing must be sought in the existence and activity of other finite things. The derivation is further augmented by the discussion that follows the Corollary:

> This indeed is self-evident. For if I suppose that a body A, for example, is at rest, if I pay no regard to other bodies in motion, I can say nothing about the body A except that it is at rest. If it should afterwards happen that the body A should move, its motion could not certainly be a result of its former rest, for from its rest nothing could follow than that the body A should remain at rest.

The second half of the proof is the exact converse of the above. What is clear from this proof is Spinoza's conception of motion as a quality of a body: a body is not undergoing any change as long as it continues in its motion, and there is no causal explanation required for this continuation of motion. This can be contrasted with the Aristotelian concept of motion, where in order to keep an object in motion, a mover is needed, and a body will come to rest when nothing causes it to

move. In a sense the body is undergoing change when it is moving.

In this respect, Spinoza's principle of inertia is no different from the equivalent statements in the Principles, where motion is spoken of as an unchanging quality (see Proposition 14, Part Two). But there is an important difference with respect to the two-sided character of the principle of inertia: in the Principles it is stated clearly only in respect to motion, and not for rest[1]. This difference is significant and should be explained a little further.

If we return for a moment to Spinoza's proof of the principle of inertia just given above, we will notice a certain peculiarity in that the proof depends on a dichotomous treatment of motion or rest: bodies are either in motion or at rest. What is not taken into account is the possibility that bodies might speed up or slow down, and what is manifestly lacking in Spinoza's principle of inertia is the phase "with undiminished velocity" or its equivalent. Both the statement of the principle and the method of proof involve a "two-state" conception of motion. The obvious problem with this is how to deal with various degrees of velocity, and it is hard to take this seriously as physical theory. But the fact remains that Spinoza does employ this terminology

and that his proof of the principle of inertia depends on it.

This peculiar terminology of Spinoza's does not apply only to the principle of inertia; if we take a closer look at the first two axioms, we see it in effect there as well. Axiom 1 states that all bodies are either in motion or at rest. Axiom 2 states that all bodies move. If we take Axiom 2 to state that all bodies are in motion, then it follows from the conjunction of the two axioms that no bodies are at rest, and this makes the principle of inertia trivial: if all bodies are in motion, then it is trivially true that bodies in motion remain in motion and all bodies at rest remain at rest. Consequently the equation of "moves" with "in motion" is not correct.

The relation between motion and rest in Spinoza's physics is not at all a straightforward matter. Two things are commonly said of this relation:

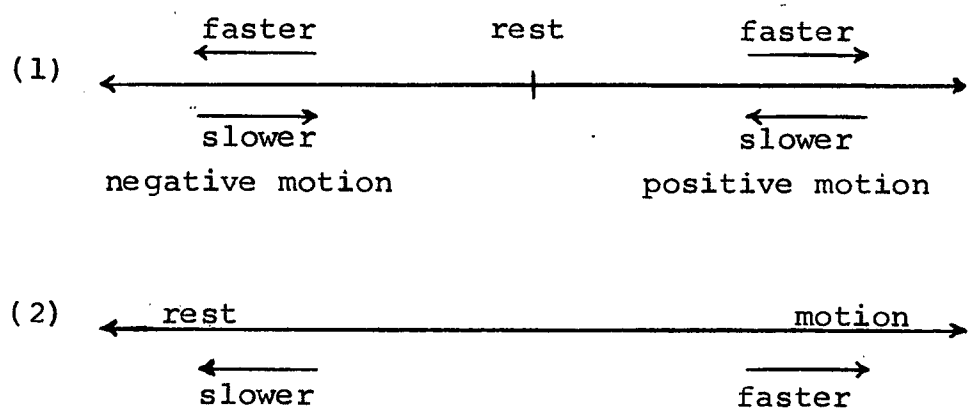
(a) rest is infinitely slow motion; i.e. the state of rest is the <u>limit</u> of a series of states of motion, each slower than the previous one, so that bodies approach a state of rest but never actually reach it.

(b) rest is a special case of motion, i.e. rest is zero velocity.

Neither of these interpretations is quite

adequate. Interpretation (a) seems to be flatly contradicted by Axiom 1, while (b) runs contrary to Axiom 2. To explain what I think Spinoza has in mind, I offer a third interpretation, which admittedly is not without problems of its own, but which, I feel, nonetheless represents Spinoza's ideas better than the other two.

Consider the following picture:



In this picture, (1) can be taken to represent the Newtonian idea of velocity as a vector quantity, while (2) represents what I think Spinoza had in mind. It should be noted that (2) represents the idea of rest as infinitely slow motion but in quite a different sense from (a) above.

In defense of this interpretation of the connection between motion and rest in Spinoza's thought, I first draw attention to the fact that in the <u>Ethics</u> he consistently pairs up "motion" with "quickness", and "rest" with "slowness", and it is really the most plausible way of looking at Axioms 1 and 2. Axiom 1 states that

any particular body is in either one of two possible states while Axiom 2 asserts that all bodies are subject to the one infinite mode under the attribute Extension, motion-and-rest.

If we ask why Spinoza arrived at such a strange and unmanageable conception, then I think we can find the answer in the Principles, and in particular we can trace a connection to the notion of quantity of rest (see pages 31 to 37). As I have already discussed in Chapter III, in the Principles there is an attempt to formulate the notion of quantity of rest. There was somewhat of a contradiction between quantity of rest as formulated by Corollary 1 to Proposition 22, which stated that the slower bodies move the greater their quantity of rest, and the effective definition of quantity of rest as used in the rules of motion: quantity of rest is proportional to the size of bodies at rest, and zero for bodies in motion, no matter how slowly (see page 37). Also he may have noted the absence in the Principles of the one half of the principle of inertia that deals with bodies at rest. By taking rest as the opposite of motion, rather than a special case of motion, he was able to formulate a complete principle of inertia and at the same time give an elegant proof of it, one that fitted in with his ideas on the self-evident nature of physical truth.

This is incidental to my main theme, and somewhat speculative, but I think we can see an interesting development of the principle of inertia from Descartes to Newton. In the Principles there is a clear statement of the principle of inertia as pertaining to uniform motion in a straight line, but it is with the other half of the principle that profound difficulties arose. These difficulties have their source in the definition of rest. Newton was able to formulate a complete principle of inertia by taking rest as zero motion and by making motion into a directed quantity, however, he could do so only by introducing the notion of space as something separate from body. But in the Cartesian universe space and body were the same, so that motion necessarily had to be conceived as a quality of a body, or a state in which it is found. Spinoza was committed to the identity of corporeal substance and extension, as I shall argue in Chapter Eight, and he is therefore led to a conception of motion and rest as correlative concepts, of motion and rest as symmetrical opposites. That he was unable to achieve a satisfactory formulation is not surprising, but it should also be remembered that Newton's solution to the problem of the principle of inertia created puzzles of its own.

Thus far I have been dealing with the first

category of laws of motion, namely those dealing with bodies in isolation. Of laws dealing with the collision of bodies, there is in the Ethics only one sample, the fourth axiom. At first sight the fourth axiom seems to play no particular role in the physics of the Ethics: nothing leads up to it and nothing follows from it. The most plausible way of looking at the fourth axiom is to consider it as something necessary to make the physics of the Ethics complete. To give a causal explanation of any physical event, it is only necessary to give a history of the motions of particles and for this a law that deals with the interaction of bodies is essential. But then, the question that comes to mind is whether the fourth axiom was intended as a perfectly general law covering all kinds of collisions, or whether it was intended only to deal with a certain type of collision, in which case we should consider it is a prototype, or sample of other, similar laws.

To try to answer this question, we should look at it a little more closely, to see just what it is that is being asserted by the axiom. The most controversial word in the axiom is the word "immovable". It might mean "practically immovable" such as in the case of a very large stationary object being struck by a much smaller one, which would mean that the axiom applies

only to special cases. "Immovable" might also mean that the object being struck is not going to be displaced, in virtue of its size, as in the case of the fourth rule of motion in the Principles; in this case, again, the axiom is not a general law of collision. The only way in which the axiom might be considered as a perfectly general law, is to read "immovable" as "considered immovable". What it might mean is that in a collision we consider only the relative motion of the two bodies involved, and for the purpose of calculating the resultant velocities, we take temporarily either of the bodies to be at rest; this is equivalent to taking a moving frame of reference in Newtonian physics. However, this line of approach introduces all sorts of complications, and since there is nothing to support the contention that Spinoza was thinking in terms of frames of reference, it seems very unlikely that this interpretation of the axiom is correct.

There is a problem here. On the one hand, the fourth axiom, since it is the only law of collision presented, might be expected to be perfectly general in character, while on the other hand, there seems to be no feasible interpretation that makes sense of the axiom as a general law. Since there is no direct textual evidence on this point, I can only offer a conjecture, which is that the fourth axiom is but one member of a group or

system of laws of motion. As to why Spinoza might have selected this particular law as representative there are two clues:

(a) The science of optics was the most highly developed of the sciences of that day. It is certain that Spinoza, as well as others, was greatly impressed by the power and precision of optical science, and quite likely saw in optics a model for all of science. Geometrical optics has two basic laws, the law of reflection and the law of refraction. My conjecture is that Spinoza saw in the law of reflection, with its obvious connection with the behaviour of small bodies rebounding off larger ones, as one of the most fundamental laws of nature, and for that reason included it in the Ethics.

(b) In the Principles Spinoza is seen to amend the fourth rule of motion. Descartes's version says nothing about collisions at an angle, and Spinoza devotes considerable space and effort to put his modified version on sound footing. The supposition, here, then, is that he felt quite confident about the soundness of this rule of motion, confident enought, at any rate, to include it in his magnum opus.

Another interesting feature of the fourth axiom is its vagueness on the subject of the conservation of motion. The phrase "in order that it may continue its

motion" is not specific enough to make the axiom into a principle of conservation of motion in collisions, or to guarantee that motion is conserved in the particular kind of interaction between bodies that the axiom is supposed to be dealing with. This is somewhat puzzling; if on the one hand, Spinoza intended the axiom to assert that motion is conserved in this or any kind of collision, why then does he not make it more specific? If, on the other hand, he does not intend the axiom to say anything about conservation of motion, how do we explain his failure to deal with this subject?

One might argue that since the Ethics is not primarily a treatise on physical science, Spinoza was not greatly concerned about conservation of motion, but I find it hard to believe that Spinoza would be so haphazard in this matter. And in any case there is some evidence that he did consider the topic important. In the letter to Oldenburg already mentioned in the previous chapter (see page 60), he describes the universe as a whole in which "the same proportion of motion and rest" is conserved. If conservation of motion is not guaranteed in individual collisions, then there is no guarantee that the whole universe will not run down, so to speak. Since, in Spinoza's thought, the universe is a system that maintains itself without any outside intervention, such

a guarantee is needed.

There remains then the task of explaining how the phrase "in order that it may continue its motion" can be construed as asserting that motion is conserved. To do this we should return to the discussion of the principle of inertia and note that what is missing in both the principle and the fourth axiom is the phrase "with undiminished velocity", and I think in both instances this omission finds its cause in the fact that Spinoza would have considered this phrase redundant. That means, then, that the phrase "may continue its motion" should be taken to read "maintains its velocity", and we can conclude with a reasonable degree of certainty that Spinoza did intend the fourth axiom to say that motion is conserved.

My major concern in this chapter has been to discuss whether Spinoza's theory of motion marks the physics of the Ethics as something fundamentally different from the Cartesian physics, and my major conclusion is that it does not. On the contrary, there is good evidence that in the Ethics he is dealing with essentially the same kind of problems as crop up in the Principles. For instance, his amendment of the principle of inertia to include a clear statement for bodies at rest, can be taken as an effort to improve on the

Cartesian physics. His conception of motion and rest as symmetrical opposites can be traced fairly conclusively to the difficulties inherent in the attempt to formulate quantity of rest in the Principles. The fourth axiom bears a close kinship to the fourth rule of motion, which he, in the Principles, is already subjecting to considerable alteration. While it is true that he does not take over from the Principles the whole set of laws of motion, the main reason may have simply been his desire to keep the amount of physical theory to a bare minimum, and even if he did have qualms concerning the validity of some of the rules of motion, there is not a shred of evidence to justify the position that he considered that kind of law to be invalid.

On the whole, the physics of the Ethics should be looked on as a continuation of that of the Principles; the former is basically a condensation of the latter, with some amendments, some deletions, and some extensions. Spinoza's writing of the Principles is often dismissed as a mere commentary on Descartes, performed mainly as practice in the use of the geometrical style of writing. I consider this a serious mistake, since to a great extent the ideas presented in the Principles are representative of Spinoza's thought.

[1]A further difference is also that in the *Principles* the principle of inertia specified motion in a straight line; this is omitted in the *Ethics*, but for precisely what reason is not obvious.

CHAPTER VII

THE CORPORA SIMPLICISSIMA

The central idea in the theory of individuals is that of organized complexity, and the very notion of an organized whole implies or presupposes the existence of simplest elements, or alternatively, an infinite hierarchy of complexity, in which any body can always in principle be analyzed in yet simpler elements. Spinoza defines the simplest bodies in an off-hand manner just after Axiom 4, but after that says very little more about them specifically. He says nothing, directly, about their size or shape, their origin or their behaviour, and worse, he fails to make clear whether there even are such things as simplest particles; in other words we are not even sure whether there actually exist simplest particles, or whether each body should always be thought of as analyzable into simpler elements.

The general literature on the subject of the corp. simp. is limited and not a great deal of attention seems to have been directed toward discovering exactly what Spinoza had in mind when he talks about simplest bodies. As an example, there is Stuart Hampshire's commentary on this topic[1]:

It was not until the end of the last century that

> his three conceptions (a) of motion-and-rest as the essential and universal feature of the extended world, and, (b) of ultimate particles as centres of energy, and, (c) of configurations of these ultimate particles forming relatively self-maintaining systems were seen to correspond with actually used scientific concepts.

More specifically about the particles, Hampshire says:

> Qualitative changes in medium-sized object, as these are described in common-sensed knowledge, are represented in the light of systematic knowledge solely as measurable changes in the velocity and configuration of qualitatively undifferentiated particles.

Hampshire's book has been very helpful on the subject of Spinoza's scientific ideas, and yet what he says leaves a great deal to be asked. For instance, does "qualitatively undifferentiated" mean that all the ultimate particles are of the same size or the same shape? Or, for that matter, in what way are the ultimate particles ultimate? Does "ultimate" mean "indivisible"? Or even, in what sense are the corp. simp. particles at all? Perhaps we should look upon them as abstract entities like the monads of Leibnitz, not really material, but which somehow account for the phenomena of the material world. All these questions have no ready answer on the basis of a superficial scrutiny of what Spinoza says in the <u>Ethics</u>.

To obtain clarification on the nature of the

corp. simp., we should direct our attention to the following question: are the corp. simp. extended, like the Cartesian particles, or are they not? For both the negative and the affirmative answers there is good evidence; this evidence is as follows:

1. Pro extended particles:

(a) Axiom 4, the only law of collision in the Ethics, speaks of a body striking the plane of another body. This clearly indicates that at least one of the parties to the collision is extended. The question then, is, does the axiom deal with simple bodies or with complex ones. That the first alternative is the correct one is shown by the sentence directly following the statement of the axiom:

> Thus much for the simplest bodies which are distinguished from one another by motion and rest, speed and slowness alone; let us now advance to composite bodies.

(b) The definition of an individual, which follows the sentence just referred to, contains the phrase: "When a number of bodies of the same or different magnitudes are pressed together". For this definition to be applicable to any individual, it must also apply to the lowest level individuals, namely those whose constituents are corp. simp.. It follows that the corp. simp. have magnitude; this, together with the

phrase "pressed together", suggests extended particles.

(c) Axiom 5, a definition of hardness, softness and fluidity, defines these in terms of the surfaces of contact between the constituents of a body. In the absence of evidence to the contrary, it is a legitimate supposition that the lowest level individuals may also be hard, soft or fluid, which makes the corp. simp. out as extended particles.

(d) Lemma 5 states that if "the parts composing an individual become greater or less proportionately..." the other conditions remaining the same, then the individual will "retain the nature it had before". The same point as made in (b) and (c) above applies here.

2. Contra extended particles:

(a) The statement following Axiom 2 describes the corp. simp. as those bodies "which are distinguished from one another by motion and rest, speed and slowness alone". This appears to exclude unequivocally the possibility that the corp. simp. vary as to size and shape.

(b) Lemma 1 states that bodies are distinguished not in substance, but "in respect to motion and rest". Also, in the Scholium after Lemma 7, Spinoza says:

> Up to this point we have conceived an individual to be composed merely of bodies which are distinguished from one another solely by motion and rest, speed and slowness, that is to say, to be composed of the most simple bodies.

Both these quotations serve to reinforce the point made in 2(a).

The crucial issue is: how can Spinoza say that the corp. simp. are differentiated solely in terms of motion and rest, and yet speak of shape, surface, and magnitude as pertaining to them? On the basis of the evidence outlined above, an obvious possibility is that the particles are extended, but are all of the same size and shape. But this makes Spinoza into an atomist, and I have not found one iota of evidence that might support this contention: as a matter of fact there is a great deal of evidence against it, especially in the nitre dispute with Robert Boyle. Furthermore, the atomist hypothesis is almost certainly irreconcilable with the denial of the existence of a vacuum. Rather than delving further into this question, we should retreat somewhat, and scrutinize the phrase "distinguished in respect to motion and rest" a little more thoroughly. The explanation that comes most readily to mind is that the phrase means that bodies differ in their velocities, but there is another way of looking at it. If we think back to the Cartesian scheme for a moment, it will be remembered

that it was the addition of motion to extension which created the particles, so that in fact the shapes and sizes of particles depend directly on only one variable, namely the distribution of motion in extension. It is correct to say of the Cartesian particles, then, that they are differentiated by motion and rest alone. It follows from this that to say that the corp. simp. are distinguished solely by motion and rest is not necessarily contradictory to saying that they have various shapes and sizes, as long as we think of them in terms of the Cartesian physics.

To support the contention that the corp. simp. are very similar to the Cartesian particles, there are the following considerations:

(a) The demonstration to Lemma 1 suggests very strongly that the lemma does not apply only to the corp. simp., but to the individuals as well. The lemmas asserts that all bodies differ in respect to motion and rest, and not with respect to substance. Now it is obvious that all bodies, such as people, apples, or stones, can be said to differ in a great many ways, which includes size and shape. The reason why Spinoza does not mention these is that he is mainly interested in making clear that bodies do <u>not</u> differ with respect to substance, whatever else they may differ in. Hence the fact that in the

definition of a simplest body he does not mention size or shape, is not as important as it seems at first sight. Also, by comparing Lemma 1 and the definition of a corp. simp. we begin to see more clearly what Spinoza has in mind. He wants to distinguish clearly between the individuals which differ from each other by virtue of their constitution, and the corp. simp., which, since they are not composite, cannot be said to differ in their constitution.

(b) A possible objection to comparing the corp. simp. to the Cartesian particles is that in the Principles a definite account is given of the origination of the particles, while in the Ethics there is nothing to suggest that the corp. simp. are to be thought of as relatively stable particles. The answer is that in the physics of the Ethics the creation of particles should be thought of as a continuous process, something that has always gone on, and will always go on. It should also be noted that the creation of particles at a definite time is in the Principles presented as a hypothesis, as something that might be reasonably supposed to have taken place, and thus is not a part of the logical structure of Part Two of the Principles: some other way of explaining how the present state of affairs came to be might be equally acceptable. In any case, to Spinoza

the creation of all the particles at a definite point in time is quite unacceptable, so that in his scheme it is not so easy to conceive of the particles as relatively enduring entities; but at the same time this does not necessarily imply a radical shift from the Cartesian physics. In both cases the detailed explanation of physical phenomena consists of describing the motions of particles of various sizes and shapes.

(c) In the dispute with Robert Boyle over the redintegration of nitre, Spinoza's arguments are convincing proof of his acceptance of the practical aspects of the Cartesian physics. Spinoza considers Boyle's experiments far from adequate for proving that nitre is heterogeneous in character. His own explanations are completely in accord with the physics of the Principles. He suggests that the main difference between spirit of nitre and nitre is "that the particles of the latter are in a state of rest, while those of the former agitate each other with no little vehemence". The salt of nitre, in his opinion, consists of particles which have holes or pores in them, in which the particles of nitre are lodged. The taste of nitre he attributes to the fact that the sharp points of the nitre particles touch the tongue. These are but a few examples of his arguments in the nitre dispute, arguments which in effect are a spirited

defense of the Cartesian physics.

Points (a), (b) and (c) discussed above are supporting evidence for the main conclusion: that the corp. simp. of the Ethics are very similar to the particles of the Cartesian physics. To sum up my argument, there is a great deal of material that points to the correctness of this conclusion, while there is in effect only one statement in the Ethics that casts doubt on it. As I have shown, there is a plausible interpretation of that statement which removes that difficulty.

The most immediate implication of this conclusion is that if we wish to study Spinoza's theories of the physical universe, we are not limited to the material of the Ethics, but we can use the Principles to clarify some of the obscurities of the Ethics. There are in the Principles undoubtedly many items that Spinoza had serious qualms about. One concerns the original creation of particles, and there is also the case of the sixth rule of motion; these are the only two for which direct textual confirmation is available. But on the other hand, there is no solid evidence that he had any objections to the basic features of the Cartesian physics, its basic premisses and its method.

A more far reaching implication of the similarity of the corp. simp. to the Cartesian particles

is that it casts a new light on the more fundamental aspects of Spinoza's cosmology. It leads to a somewhat different interpretation of his doctrine of Substance, Attribute and Mode, to the one that is generally accepted. I will deal with this further in the next chapter.

It may seem that Spinoza's agreement with the basic features of the Cartesian physics makes him of lesser importance as an original thinker and more of an expositor of the ideas of Descartes, at least in the realm of physical science, but I feel this impression is false. Instead of merely expounding Descartes's views, he is engaged in the task of sorting out the more fundamental aspects of the Cartesian physics in order to put it on a sounder footing, and he is grappling with the profound contradictions inherent in the system.

In this thesis I have largely avoided the topic of the modernity of Spinoza's ideas. One reason is my feeling that any parallel between Spinoza's ideas on the structure of the physical universe and modern philosophies of science are at the best very tenuous. Besides, I am certain that Spinoza's physical theories do not need any apology, any effort to put them in a better light. A cursory reading of the <u>Principles</u> perhaps creates an impression that the physical theory it presents is a bit naive; a closer examination reveals that it is

definitely more than a collection of implausible laws of motion, that it deals with the extremely abstruse issue of the metaphysical foundations of science.

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[1] See Hampshire, page 79.

CHAPTER VIII

MOTION AND PARTICLES

My contention is that Spinoza's conception of the structure of the physical universe is basically the same as the Cartesian one; that is, the universe is a plenum, filled with particles of various sizes and shapes which fit together so that there is no vacuum, and scientific explanation is in terms of the interaction, by contact alone, of the basic particles. The evidence for this contention falls into certain major categories which I will discuss more or less systematically.

1. In the physics of the Ethics there is really only one statement that does not fit in with the interpretation of the corp. simp. as extended particles of various sizes and shapes, namely that the simplest bodies are distinguished by motion and rest alone. This statement, as I have discussed in the previous chapter, seems to imply that the simplest bodies are not different in size and shape, which is in contradiction with the Cartesian scheme. However, as I have mentioned, there is a plausible explanation for this discrepancy, in that in the Cartesian scheme, it was the addition of motion to extension which created the particles so that the shapes and sizes of the particles depend directly

on only one variable, namely the distribution of motion in extension. Therefore, in a strong sense, it is true of the Cartesian particles also, that they are differentiated by motion and rest alone.

2. Throughout his writings, Spinoza shows a deep concern for the problems of the continuum; his undoubtedly strong interest in these problems is most readily explained if his concept of the structure of the physical universe is based on the same basic premisses as those of the Cartesian physics, the main premiss being that corporeal substance and extension are one and the same.

Already in the Principles we find a concern with the problems of the continuum. In the Scholium to Proposition 6, Part Two, there is a discussion of some of the paradoxes of Zeno; the paradoxes are described as arising from the illegitimate division of the continuum into parts, time into moments and motion into units of velocity. In the letter to Mayer, April 1663, which is greatly significant with respect to this topic, Spinoza deals extensively with the topics of time, duration and extension in terms of the continuum. For example, he asserts that if it is assumed that time is composed of moments, it would not be possible to understand how an hour could pass:

> For in order that the hour may pass it will be necessary for the half of it to pass first, and then a half of what remains of the remainder; and if you thus go on indefinitely, subtracting the half of what is left, you will never be able to reach the end of the hour. Therefore, many who have not got used to distinguishing the things of reason from real things, have dared to declare that Duration is composed of moments.

It should be noted that here, as well as in other of Spinoza's discussions, he attempts to solve the paradoxes by means of his theory of knowledge. Here he contrasts "things of reason" with "real things", while in other instances he emphasizes the distinction between the intellect and the imagination. Whether the distinction between "things of reason" and "real things" is the same as the distinction between the intellect and the imagination is one problem; more generally, how Spinoza attempts to resolve the paradoxes of the continuum involves a thorough examination of his theory of knowledge, which is definitely beyond the scope of this thesis. The main point is that he devotes considerable attention to the paradoxes of the continuum and that these are very much at the centre of his thought.

From Spinoza's discussion of the paradoxes of Zeno I think his intense interest in the problems of the continuum is abundantly clear, but so far we have seen no clear connection between the paradoxes of Zeno and the problems of the continuum generated by the

identification of physical substance with geometrical space in the Cartesian physics. That these two are indeed connected, we can see from the long Scholium to Proposition 15, Part One of the Ethics. In that Scholium Spinoza defends the position that God can be a corporeal being and at the same time be both infinite and simple, i.e. not divisible or consisting of parts. He does so by attacking the arguments of those who believe that God cannot be an extended being because physical substance is necessarily finite and hence cannot properly pertain to God who is a perfect being. He represents some of the arguments of his opponents as follows:

> If corporeal substance, they say, be infinite, let us consider it to be divided into two parts; each part, therefore will be either finite of infinite[1]. If each part be finite, then the infinite is composed of two finite parts, which is absurd. If each part be infinite, there is an infinite twice as great as another infinite, which is also absurd. Again, if infinite quantity[2] be measured by equal parts of a foot each, it must contain an infinite number of such parts, and similarly if it be measured by equal parts of an inch each; and therefore one infinite number will be twelve times greater than another infinite number.

Spinoza states that the fallacy of his opponents' argument lies in their "...suppostion that bodily substance consists of parts", a supposition which he considers to be absurd. He says:

> And indeed it is not less absurd to suppose that corporeal substance is composed of bodies or parts than to suppose that a body is composed of

> surfaces, surfaces of lines, and that lines, finally, are composed of points. Every one who knows that clear reason is infallible ought to admit this, and especially those who deny that a vacuum can exist.

So far Spinoza's arguments consist mainly of accusing his opponents of absurdities; we would naturally like to know how he resolves the problems that arise from the supposition that corporeal substance is infinite. His solution is best expressed by the following passage in the same Scholium:

> If, nevertheless, any one should ask why there is a natural tendency to consider quantity as capable of division, I reply that quantity is conceived by us in two ways: either abstractly or superficially; that is to say, as we imagine it, or else as substance, in which way it is conceived by the intellect alone. If, therefore, we regard quantity (as we do often and easily) as it exists in the imagination, we find it to be finite, divisible, and composed of parts; but if we regard it as it exists in the intellect, and conceive it in so far as it is substance, ..., we find it to be infinite, one and indivisible.

In the letter to Meyer, Spinoza sees the paradox arising out of the failure to distinguish between things of reason and real things; here he gives his solution to the problem of divisibility of substance in terms of the intellect and the imagination. This same theme is evident in Chapter Two of the Short Treatise, where he discusses the same topic, the divisibility of corporeal matter and the simplicity of God. There he says "Part and whole are not true or real entities, but only things

of reason".

In all these various instances of Spinoza's involvement with the problem of the infinite, it is obvious that there is something very important at stake for his system, and what I think is at stake is the viability of the Cartesian physics as a cosmology. In Chapter Three I have mentioned some of the conceptual puzzles that arise naturally out of the identification of corporeal substance with extension. The fact is that there is a basic contradiction in picture of the universe as extension which is cracked by motion to create the world of variety and change. As long as we think of extension as some sort of glassy substance[3], perfectly homogeneous and extending indefinitely in all directions, then we can easily visualize it breaking up into myriads of fragments and this picture seems quite plausible. However, in the Cartesian physics this glassy substance is not substance or material of any kind, it is pure extension, geometrical space. The basic contradiction is between thinking of corporeal substance as being perfectly homogeneous, a continuum, and yet at the same time thinking of it as consisting of parts, the same contradiction that, in Spinoza's view, leads to the paradoxes of Zeno.

3. Spinoza's views on the vacuum reinforce

the points discussed above. Both in the Scholium to Proposition 15, Part Two of the Ethics and in Chapter Two of the Short Treatise Spinoza's discussion of the unity of physical substance is coupled with a denial of the existence of the vacuum. Spinoza's argument is exactly the same as that of the Principles. The vacuum is a logical absurdity, "something positive and yet no body", as he puts it in the Short Treatise. In the Scholium just mentioned, Spinoza makes a close connection between the unity of physical substance and the existence of a vacuum:

> For if corporeal substance could be so divided that its parts could really be distinct, why could not one part be annihilated, the rest remaining, as before, connected with one another? And why must all be so fitted together that there can be no vacuum.

Spinoza considers that a gap in the continuum is contradictory to the very notion of a continuum. The above passage indicates pretty clearly that Spinoza thought of the unity of physical substance not on some abstract metaphysical plane, but in rather concrete, down-to-earth terms, unless, of course, he was not speaking about the same kind of vacuum which was being investigated experimentally by Boyle and Von Gueriche, which seems highly unlikely[4]. His arguments are most easily understood in the framework of the Cartesian physics.

4. Spinoza's ideas on the nature of scientific method are subtle and not easily categorized, but at the same time in the style of his arguments and the character of his writing there is a great deal of similarity to the basic method of the Principles. The Principles has as opening statement the following:

> It is only asked here that each one attend as accurately as possible to his concepts in order to be able to distinguish the clear from the obscure.

This statement applies to the method of mathematics and especially to geometry. That Spinoza had great faith in the method of geometry which proceeds from self-evident truths to less obvious but logically indisputable truths is evidenced by his selection of the geometrical style of writing in both the Principles and the Ethics. In the letter to Oldenburg of April 1662, Spinoza criticizes Boyle's attempt to prove the particulate nature of matter by experiments:

> One will never be able to prove this by chemical or by other experiments, but only by reasoning and calculation. For by reason and calculation we divide bodies infinitely;...

In the Ethics he presents his principle of inertia not as a property of matter or as a hypothesis about nature, but as something which "is indeed self-evident". Hardness, softness and fluidity are not described as gross properties of matter which we must

try to account for, but rather are defined as depending on certain properties of particles. All in all he exhibits considerable confidence in the possibility of arriving at the basic physical truths by the process of arguing from the nature of the concepts themselves, concepts such as substance, body, extension, and motion.

5. There are a great many metaphysical issues on which Descartes and Spinoza are considered to hold diametrically opposed views, and it may therefore be thought to be surprising that their cosmologies are so similar, as I have suggested. Of course, it is not feasible to discuss all these issues to show that the different philosophies are not reflected in their cosmologies, but there is one item that should be examined more closely, especially since it is in connection with that item that Spinoza outrightly condemns the whole Cartesian physics. In the letter of May 1676, to Tschirnhaus, Spinoza says:

> From extension as Descartes conceives it, that is, as a quiescent mass, it is not only, as you say, difficult to prove the existence of bodies, but absolutely impossible. For matter at rest will continue at rest as much as possible, and will not be set in motion except by some stronger external cause. For this reason I did not hesitate to say once that Descartes's principles of natural things are useless, not to say absurd.

About this passage Wolf[5] says the following:

> The use of the same term Extension by Spinoza and Descartes has unfortunately obscured for most people the enormous difference between the Cartesian and Spinozistic conception of the ultimate nature of matter. For Spinoza, Extension or Matter is essentially physical energy. It expresses itself in the infinite mode of motion and rest, which consequently need not be introduced miraculously from the outside, as was the case in Descartes's scheme of things.

That there is a great difference between Spinoza's and Descartes's scheme of things is a comment frequently made[6], but what precisely is this difference? What is at stake is whether motion is something separate from physical substance or an inherent part of physical substance. In the Principles the creation of particles by motion was described as having taken place in the beginning, when God created the visible world; all the original particles were produced in one fell swoop. In Spinoza's philosophy this "one-shot" creation of the particles is absurd; consequently this creation of particles in Spinoza's physics is more of a continuous process, something that has always gone on and will go on forever. Superficially, it does not make a great deal of difference how or when motion came into the world, as long as the present description of the universe is unaffected. However, there is a subtle but far-reaching difference in emphasis: in the Cartesian physics the emphasis is on particles, which are to be considered as enduring entities,

on the whole, even though they fracture or fuse occasionally (how, when or why is largely a mystery). In the Spinozistic picture the idea that motion is the cause of the character and the existence of the particles is taken much more seriously and consequently the particles are to a lesser extent real or concrete existents. To put it a little differently, in the Cartesian physics scientific explanations deal essentially with the motions and interactions of particles, while in Spinoza's physics the scientific account basically concerns itself with the distribution of motion-and-rest in the universe.

The general picture of the cosmos as one in which the fundamental variable is the distribution of motion and rest is difficult to visualize and even harder to describe. The physical universe is space, or emptiness, which is "shot through", so to speak, with motion and rest. Superficially, the Cartesian and Spinozistic scientific schemes are the same: both deal in terms of particles in motion, but the emphasis is quite different. In the Cartesian system a composite body is a conglomeration of particles, while in Spinoza's system it is appropriate to say that "the human body, therefore, is nothing else than a certain proportion of motion and rest" (Appendix Two, Short Treatise).

The arguments I have presented in the above

five points demonstrate clearly, I submit, that Spinoza was satisfied in the main, with the kind of physical theory presented in the Principles, and that his criticisms of Descartes are directed not so much at the Cartesian physics, as at the metaphysical foundations of that system of physics. It explains why Spinoza presented so little physical theory of his own, and why the general character of the physics of the Ethics is quite compatible with that of the Principles. At the same time we should note, however, that he gives the Cartesian physics, by fitting it into his own metaphysical scheme, a distinctly different flavour, so to speak. Or, putting it a little more strongly, it is possible to look upon his metaphysics as a development of the Cartesian physics, a result of the efforts to deal with the puzzles created by the Cartesian scheme. His doctrine of substance, attribute, and mode, can be seen as arising from the effort to construct a scheme to explain the relations between extension and motion. His distinction between infinite, or mediate modes and finite modes can be interpreted in terms of motion breaking up continuous space into the world of particulars. The theory of individuals could be considered as an effort to found a theory of organized complexity in order to explain the interconnection of mind and body; in the Cartesian system this is not needed since mind

and body are separate substances. Spinoza's three kinds of knowledge can be seen as directly related to the three different ways of looking at the universe: with Imaginatio we see the world of sights, sounds, smells, etc.; with Ratio we see the world as made up of particles in motion, while with Scientia Intuitiva we see corporeal substance as extension, continuous and indivisible. His distinction between Ratio and Scientia Intuitiva can be seen as an effort to solve the paradoxes of the infinite, while his proofs of the unity of physical substance apply directly to the Cartesian cosmology.

All this is somewhat speculative and goes well beyond the scope of this thesis, but it serves to emphasize the necessity of paying close attention to Spinoza's physics. His writing of the Principles is usually dismissed as something of incidental interest, while the physical theory contained in the Ethics has not had the benefit of a detailed analysis. His views on the vacuum are ignored by and large, and his concern with the paradoxes of Zeno has not been considered very significant with respect to his major doctrines. My effort has been to show that all these topics, which at first sight are quite unconnected, do hang together, and that together they indicate that Spinoza's ideas on the nature and structure of matter are not radically different from,

or totally unconnected with those of René Descartes; that in spite of metaphysical disagreements, Spinoza's and Descartes's scientific theories are quite similar. The central issue to which I have devoted my attention is the nature of the corpora simplicissima in Spinoza's system and what role they play in his conception of the physical universe as consisting of particles in motion. My conclusion, that the corpora simplicissima are extended particles very similar to those of the Cartesian physics, has not only a definite bearing on Spinoza's scientific theories, but has important implications for the interpretation of his philosophy as a whole.

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[1]What is at stake here is the fact that an infinite set can be put into a one-to-one correspondence with a proper subset of that set.

[2]Spinoza frequently seems to identify physical substance with quantity. This is also done in the Principles; see, for instance, the definition of extension (Definition 1, Part Two).

[3]There is an inviting parallel between the notion of the universe as infinite extension, perfectly homogeneous and changeless and Parmenides's idea of the universe as a homogeneous sphere. With both Parmenides and Spinoza there is the problem of reconciling a timeless, changeless whole, with the perceived world, which is full of variety and change.

[4]See, for example, the letter to Oldenburg, July, 1663.

[5]See Wolf, page 62.

[6]See, for instance, Hampshire, pages 70-71.

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APPENDIX A

SPINOZA'S LIBRARY

I have included this item because it casts a light on Spinoza's interest in science, and also because the list is hard to find, especially in English works. This selection is taken from the list in Freudenthal's Die Lebensgeschichte Spinozas which contains 161 items. It includes works written in Latin, Hebrew, Spanish and Dutch. Most of the books relate to Spinoza's philosophical, theological and political studies, but the selection I have made deals mostly with astronomy, medicine, physics and mathematics. Freudenthal's list is believed to be incomplete, the more valuable books having been removed before the inventory was made. It is unfortunate that the auditor used abbreviations or short titles.

I have translated the Dutch titles in brackets after the original title.

- Longomontani Astronomia danica cum appendice de stellis Novis et Cometis. 1640. Amstel.
- Diophanti Alexandrini Arithmeticorum Libri 6 Paris. 1621. Gr. Lat.
- Vietae opera Mathematica. Lugd. 1646.
- Hugenii Zulichemii Horologium Oscillatorium. Paris. 1673.

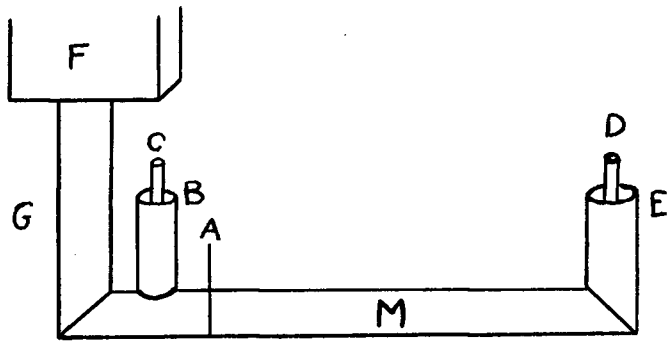
- Veslingii Syntagma Anatomicum. Patavii. 1647.
- Riolani Anatomica. Paris. 1626.
- Descartes Brieven. (Letters of Descartes)
- Kerckringii Specilegium (!) anatomicum. 1670.
- Descartes Proeven. (Descartes's proofs)
- Renatus Descartes de prima Philosophia.
- Renatus Descartes de Geometria.
- Renatus Descartes de Philosophia prima.
- Descartes opera Philosophica. 1650.
- Descartes de homine.
- a Schooten Exercitationes Mathematicae.
- Een Rabbinsch Mathematisch boeck. (a rabbinical mathematical book)
- Snellii Tiphys Batavus.
- Gregorii Optica Promota Lond. 1663.
- a Schooten Principia Matheseos Univers. 1651.
- Lansbergii Comm. in Motum Terrae. Middelb. 1630.
- Lansbergii Cyclometria nova.
- Algebra door Kinckhuysen. (Algebra by Kinckhuysen)
- Gront der Meetkunst door Kinckhuysen. (Foundations of geometry)
- De Meetkunst door Kinckhuysen. (Geometry by Kinckhuysen)
- Lansbergii Progymnasmata astron. Restituta.
- Wouter Verstap. arithmetica.
- Bartholini anatomia. 1651.

- Metii Alcmariani Instit. astron. Libri 3.
- Tulpii Observationes Med. 1672.
- Boyle de Eleatere et gravitate aeris. 1663. Lond.
- Kekkermanni Logica.
- Metii Astrolabium.
- de Graefs driehoeksmeting. (trigonometry)
- Klauberghs uytbreiding van Descartes. (Klaubergh's commentary on Descartes)
- Hobbes Elementa Philosophica.
- Boyle Paradoxa Hydrostatica.
- Euclides.
- Stenonis Observ. anat.
- Pharmacopaea Amstelred.
- Elementa Physica.

APPENDIX B

THE HYDROSTATIC EXPERIMENT

The description of this experiment of Spinoza's is found in his letter to Jarig Jelles of September, 1669. The experimental apparatus employed by Spinoza is fairly simple and his drawing, which I have reproduced below, is almost self-explanatory.



The tube, M, is 10 feet long and has a bore of 1 and 2/3 inches. We may assume that the other tubes are drawn roughly to scale. The letter "A" designates a kind of gate or valve, while Spinoza also had a way of blocking off tube B, not shown in his diagram. The first part of the experiment need not detain us for long; its purpose is to determine to what height the water will rise in small tube C with gate A closed off and to compare this with the height the water reaches in C and D with A open. Spinoza's conclusion is that the fact that E is farther removed from G than B has no effect on the level to which water rises in C and D, and more generally that

the length of tube M is not a relevant factor.

The second part of the experiment is more a hydrodynamic experiment than a hydrostatic one, because Spinoza proceeds to compare the rates of water flow through tubes B and E (the small bore tubes C and D are removed for this experiment). In order to do that he measures the time taken to fill a vessel of one cubic foot capacity by water flowing out of tubes B and E respectively. Relative times are measured by weighing the amount of water siphoned from one vessel to another at a lower level through a narrow glass tube in the shape of the letter J. Spinoza's reason for using what is accurately described as a water clock is simply that he does not have a pendulum clock available; in any case the water clock is probably accurate enough for his purposes.

Spinoza observes that the only time that there is a significant difference in the rates of flow through B and E is at the beginning, when E is slower. Otherwise, he concludes, it would make no difference whether M is 10 feet long or 40,000 feet long; that is, he concludes that the terminal rate of flow is independent of the length of tube M, but depends only on the level of water in the container F. This conclusion is correct provided that friction and viscosity effects are ignored.

In his efforts to explain why the water flow

is smaller in E at the beginning Spinoza gives a formula that is supposed to govern the rate of acceleration occurring in the water:

> For it is certain that if the water in the tube G imparts to the water in the tube M one degree of speed in the first moment, then in the second moment, it if retains its original force, as it is supposed to, it will communicate four degrees of speed to the water, and so forth. Until the water in the long tube M has received just as much velocity as the gravitational force can give the higher water, contained in the tube G.

The mystery about this statement is where Spinoza got if from. It certainly does not follow from any experimental observations nor does he say that it is supposed to. What Spinoza is asserting is that the velocity is proportional to the square of the elapsed time: $V=at^2$. About this, Wolf[1], says the following:

> Spinoza must be thinking of the <u>distance traversed</u>. This is proportional to the <u>square</u> of the time. The actual velocity developed by a body under the action of a constant force is simply proportional to the time.

Wolf is right about bodies moving under the influence of a constant force; this is just the relation $v=at$. This proportionality of velocity and time was already discovered by Galileo in 1609 from his observations of balls rolling down inclines. But in this particular case both Wolf and Spinoza are wrong, because the acceleration is not constant; it is greatest when the water starts flowing and decreases linearly until it reaches zero when the

water reaches terminal velocity, so that the relation between time and velocity is much more complicated. Quite aside from whether Spinoza was right or wrong in making this statement, there is still the question on what basis he makes this statement. The letter to Jelles is the only occasion on which Spinoza even mentions acceleration, so that it is impossible to make comparisons. We might suppose that Spinoza was acquainted with the work of Galileo, even though no works of Galileo were found in his library, and that he made a little slip here, as Wolf suggests. But all this is highly conjectural.

The chief point of interest in the hydrostatic experiment is that it shows that Spinoza, when he was so inclined, was quite capable of conducting fairly elaborate experiments. It may be said that the hydrostatic experiment is a fairly simple and straightforward experiment, and indeed, it pales in comparison with the extensive and thorough experimental work of a man like Robert Boyle, but we should look on it as a sample of what Spinoza might have done, had he been more interested. Also, from the description that Spinoza gives of the experiment, even though it is very concise, it can safely be said that he shows at least some competence as an experimental scientist. He seems to be aware of the necessity of controlling the relevant variables in the

experiment, and his observations are made carefully. He takes note of the possible sources of error and his major conclusions are soundly based on the observational evidence.

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[1] See Wolf, page 435.

APPENDIX C

THE SIXTH RULE OF MOTION

It is of some interest to explore what reasons Spinoza might have had for changing Descartes's sixth rule of motion. Descartes's version, which is found in paragraph 51 of Part Two of his Principles of Philosophy reads as follows:

> If C, at rest, is equal to B which approaches it, the latter must transfer some of its motion to the former, and rebound with the rest; for example, if B approach C with four degrees of speed, it will transfer one and with the other three return to the side whence it came.

Descartes's reasoning involves considering three cases: (a) B and C move along together with two units of velocity, so that B loses two units and C gains two units of velocity, (b) B is reflected with four degrees of velocity while C remains at rest, (c) B is reflected with less than its original velocity while C gains whatever B loses. In all three cases, it will be noted, quantity of motion is conserved. Case (a) is rejected because it involves changing C from rest to motion, while B is not reflected; somehow this is not considered perfectly equal "treatment". B and C are equal in size and hence are equally "strong", so that the results should be equal for them. Case (b) is rejected because

it "favours" C over B. Hence (c) is the correct result. In case (a), which favours B, B loses 2 units of velocity. In case (b), which favours C, B loses zero units. Since neither B nor C is to be favoured, the result must be half-way between case (a) and case (b), which means B will lose one unit of velocity and C gains one unit of velocity. Q.E.D.

This whole line of reasoning is obscure and peculiar. For instance, it is not at all clear why certain other possibilities are excluded; consider the following: B stops dead and C carries on with four units of velocity, or the following: B rebounds with two units of velocity and C is impelled with two units of velocity. Both these possibilities obey the law of conservation of motion and seem "fair" to B and C.

Spinoza's argument has the same character as that of Descartes's. He also poses three possibilities and rejects two of them as counter to the hypothesis, which is that A and B are equal. The major difference is that Spinoza does not carry the argument from symmetry as far as Descartes does, and therefore stops short of specifying the resultant velocities. Exactly why he does so is difficult to discover, however. He may have found something repugnant about "splitting the difference"

between two cases both of which are contrary to the hypothesis. He may have found something wrong with equating a change from four to three units of velocity with a change from rest to one unit of velocity. Or he may have considered Descartes's whole line of argument rather shaky and felt it was safer to restrict himself to a more limited conclusion. For lack of evidence as to exactly what Spinoza considered wrong in Descartes's argument, we can only conclude that he probably thought it was fallacious in one way or another. This indicates that Spinoza's arguments in the Principles are not merely faithful copies of Descartes's reasonings, but that the arguments are thought through carefully and stated in his own terms. This means, then, that if we are trying to decide how Spinoza felt about the Cartesian physics, we must look for clues in the basic premisses of that system, and not so much in its details.