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THE EARLY EPISTEMOLOGICAL THOUGHT OF ISAAC NEWTON

by

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PREFACE

Sir Isaac Newton (1642-1727) is the most important and most intriguing figure of the scientific revolution. He stands head and shoulders above a crowd containing men like Robert Boyle, Galileo Galilei, Robert Hooke, René Descartes, G. W. Leibniz, Johann Kepler, Christiaan Huygens, etc.--*the* genius of an age of genius. His stature is such that he appears an almost isolated figure somehow creating his magnificent theory godlike, *ex nihilo*. But Newton was a product of his age, as everyone must be, and when we look at Newton's intellectually formative years as a student at Trinity College, Cambridge (1661-1665) and immediately thereafter (1666-1669), we find that it was a time of voracious reading of the works of many important scientists and philosophers of the scientific revolution.

This paper will be concerned with determining what Newton was reading during this period and the possible influence of what he read on his philosophical thought and more particularly on his epistemological views.

The importance of such an inquiry is clear when one considers that the time of Newton's greatest scientific creativity (the year 1665/1666, the so called *annus mirabilis*) came in the midst of the period we are considering. The publication of the Principia and the Opticks were not to come for another eighteen and thirty five years respectively, yet when we look at the epistemological views inherent in those works and their later editions we find, as in the case of the scientific ideas, the thoughts of that earlier period at Trinity College and at home at Woolsthorpe Manor when he first turned his mind to the problem of the nature of the physical world and how man can come to know it.

I would like to thank the Fellows and students of Wolfson College, Oxford and Darwin College, Cambridge where a large part of this dissertation was written. I would also like to thank the staffs of the Duke Humfrey Library of the Bodleian Library, Oxford; of the Trinity College Library, Cambridge and of the Manuscript Room of University Library, Cambridge. Special thanks are due Professor Arnold Koslow who introduced me to the early manuscripts of Isaac Newton.

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CHAPTER I

PHENOMENALISM AND THE PRIMARY-SECONDARY QUALITY DISTINCTION

The history of the sciences in the seventeenth century is interestingly tied to the distinction between primary and secondary qualities. This distinction is basically one between those qualities that are "in" the object (the primary qualities), and those that arise from the interaction between the object and the observer (the secondary qualities). Thus the primary qualities exist independently of the possibility of our observing them, whereas the secondary qualities are dependent on at least that possibility for their existence. The primary qualities are considered to be necessary conditions for the existence of the secondary qualities and under suitable conditions the causes of the secondary qualities. Philosophers and scientists who have maintained this distinction have differed on which particular qualities were primary and which secondary, on what is meant by the assertion that the primary qualities are "in" the object, on whether the possibility of being experienced or that of actually being experienced is a necessary condition for the existence of secondary qualities, and in what way the primary qualities "cause" the secondary qualities.

The distinction, or at least some form of it, goes as far back as the atomists but makes its way into the seventeenth century in the works of Descartes, Galileo, Hobbes and Boyle,[1] all of whom saw it as an important aspect of the "new science."

In so far as science was to concern itself with uncovering the reality that lay behind the appearances of phenomena it was to concern itself with primary qualities--qualities that were in the objects themselves, or which at least were representations of real properties of objects. John Locke, above all others, argued for the importance of this distinction for the new science and quite explicitly saw it as the epistemological basis of the methods of Newton. The explanation of the world in terms of mass, velocity, position, time and force was an explanation of the world in terms of its real properties. And it was Isaac Newton that had shown that this program could be carried out. Indeed Locke, personally acquainted with Newton and unable to cope with the mathematical intricacies of the Principia, apparently asked for, and received help from Newton, in writing a simplified precis of that work.[2] The two men spent periods of time together from 1689 on, and it is certain that they had influence on each other's thought. Further, they were both influenced by the early members of the Royal Society, most importantly by Robert Boyle. Indeed, Locke saw himself as laying the epistemological foundations for the new sciences and the sciences were kept constantly before his eyes.[3]

It will be maintained here, however, that Newton was not so much a subscriber to the Lockean theory of knowledge as either Locke or their contemporaries surmised. The problems that were to trouble Berkeley concerning the Lockean epistemology in the years 1707 and 1708 were troubling Newton, in another context, perhaps as much as thirty five years earlier. Berkeley thought he recognized in Newton an essentially kindred philosophical soul that had adopted the proper philosophical stance as exemplified in the injunction <u>hypotheses non fingo</u>, but who had either failed to see, or having seen had ignored, the full import of that stance. It will be shown, however, that Berkeley was wrong about the significance of Newton's apparent adherence to the new principle of human knowledge, <u>esse est percipi</u>; although there were good reasons for him to be misled. There are indeed phenomenalistic elements in the Newtonian view but they spring from a different source than those of Berkeley. Whereas Berkeley's epistemological views are rooted in an anti-scepticism directed against those sceptics who doubted the validity of the senses and our ability to have knowledge of the existence of real objects like bodies or souls,[4] and in the conviction that he had triumphantly and finally laid the sceptic low, Newton's epistemological views were rooted in a healthy respect for the sceptic's arguments. This is not to say that Newton was in any way in doubt about the system that was the Principia but rather that he recognised a wide area that, for the moment at least, lay outside the scope of his method. It was in this area that the sceptic held sway and it was here that Newton framed no hypotheses. It was here too that phenomenalistic elements came to the fore. It was through a consideration of these that he found the justification that he needed to admit that this was an area that his intellect had to leave uncharted.

Galileo had also marked out such an area for himself seeing it as a place where only "fantasy" was possible at the moment. It is most interesting to note that the point concerning which both Galileo and Newton felt constrained to state that they could go no further was the same. In the Discourse Concerning two New Sciences, just after Salviati defines uniform accelerated motion as equal increments of velocity in equal increments of time and just before the statement of the laws of falling bodies, Galileo has Sagredo put forward a speculative theory of nonpermanent impetus. Salviati listens to this theory with interest but dismisses it as dealing with something that can only give rise to fantasies and states that the Author does not wish at this time to deal with causes but wishes only to describe accelerated motion.[5]

Newton's <u>hypotheses non fingo</u> arises in a similar context, for it is in answer to the question, what is the cause of gravity? that Newton offers it. Newton has gone beyond Galileo in developing a law that describes a regularity of which Galileo's law of falling bodies is a special case, but he has not gone one step further in stating the mechanism of the cause of the accelerated motion of Galileo.[6]

Although no precise specification of the boundaries of this "area" is possible on the basis of the writings of Newton and Galileo, it would seem to be characterized by the failure to determine the causes of certain "fundamental" phenomena without recourse to occult qualities. Newton, Galileo, Boyle and the others of the period were themselves unclear as to what was and what was not beyond the scope of scientific knowledge; the wavering of Newton, for instance, between whether certain causes could or could not be known will be seen in the ensuing chapters. The importance of determining the boundaries of this area of fantasy or ignorance for the seventeenth century, however, is perhaps best seen in the fact that John Locke saw it as the subject of the most important work on epistemology of the century, his <u>Essay Concerning Human Understanding</u>. We will be returning to this issue in almost every chapter of the present work since scepticism and the limits of human understanding are constant themes in the works we will be considering. But let us now return to Galileo.

Galileo's entire methodology can be viewed as ultimately resting on his distinction between primary and secondary qualities, for this distinction offerd us one way in which he may have been led to mathematicize the world.

> This man stretched his readers' minds to the utmost: in thought he dilutes to the vanishing point the accidental colors of objects. He sharpens and straightens their dimensions and edges (razor-like). He is ever subtly smoothing their motions-leaving us at last with the ideally abstract case: colorless, tasteless, soundless, frictionless. This abstraction lacks the thousand accidental features that actual phenomena are heir to. Thus does Galileo force us to mark and remark the essential formal aspects of dynamical phenomena. Thus does physics seem increasingly like pure mathematics, <u>plus</u> some additional parameters involving masses, forces, velocities, etc.[7]

Berkeley's criticisms of the primary-secondary quality distinction leads one to wonder at the fact that this distinction could allow us to mathematicize the world. Perhaps the distinction between qualitative and quantitative properties has really been the dominant one from the beginning and that the primary-secondary quality distinction is subsidiary or even reducible to it. The primary-secondary quality distinction is after all tied historically through Democritus to the attempt to give an account of change, and, since the atomists' answer to Parmenides, this account has been to make change a matter of degree and not kind. Even the so called qualitative science of Aristotle led in the fourteenth century to the quantitative treatment of the intensification and remission of qualities.[8] From the beginnings of the distinction in the thought of Democritus[9] it was used to explain qualitative change in observable objects through changes is some of the primary qualities of unobservable objects that are never conceived of as having anything but primary qualities, viz., atoms. The primary-secondary quality distinction leaves no entities actually having secondary qualities; the objects of our experience only appear to have them and atoms have only primary qualities. While the collections of atoms that are really the objects of our experience (or at least their cause) thus appear to have secondary qualities, no single atom can offer such an appearance for it has no appearance at all. Each atom is without secondary qualities not only in reality but also in appearance. Secondary qualities are then nothing but sensations produced in our minds by the interaction of atoms and our organism. The philosophers who maintain the primary-secondary quality distinction are then, in a significant sense, holding two quite distinct propositions. They assert that secondary qualities are the mere possibility of our having sensations and thus objects are the locus of the possibility of a set of sensations, while also asserting that objects and their primary qualities are real and exist independently of even the possibility of their causing sensations in us. Or to put it metaphorically, they are phenomenalists with respect to secondary qualities and realists with respect to primary qualities. When the primary-secondary quality distinction is pressed hard as it was by Berkeley in the

Principles, we are left only with a form of phenomenalism.

It would be conducive to our inquiry if we were to pick out a thesis that is common to a great many metaphysical and epistemological views and designate it by a single term. The thesis is that the immediate objects of perception are sensations (sense data, percepts, impressions, ideas, etc.). For a lack of a better term, I will call this thesis the phenomenalistic thesis, and characterize all the very many theories that contain it, as forms of phenomenalism. The position that is usually called phenomenalism does, of course, contain this thesis, but goes on to maintain that objects are then the permanent possibility of such sensations. Given our new use of the term "phenomenalism," this will constitute only one form of phenomenalism.

Views as diverse as representational realism (within the confines of the primary-secondary quality distinction) and Berkelian idealism are phenomenalist under this broad definition. Nonetheless this definition is quite useful, for both the historical roots and the ultimate flowering of phenomenalism are all brought together by it. Thus Descartes becomes a phenomenalist under our definition since he divided perception into sensation and judgment making sensations the immediate objects of awareness. He is differentiated from other phenomenalists, in our sense, in the way in which he dealt with the relation of material objects to perception-- it being God's beneficence that can assure us that material objects can be known through sensations and the proper employment of the faculties of reason and will.

The fundamental problem of the phenomenalist position as thus conceived, is the nature of the relation between what are ordinarily termed "material objects" and our sensations. We can distinguish between various kinds of phenomenalism in our sense by reference to the different views as to the nature of this relation; whether it be as in realism one of causation or as in idealism one of logical construction. Issues of ontology are clearly tied to this relation. In a pure representational realism all the qualities of objects are real in the sense of their existence being independent of being perceived. In the semi-representational realism of Locke the primary qualities are real in this sense whereas the secondary qualities are not. Finally in the idealism of Berkeley no qualities are real in this sense and our sensations are not representations of anything, except, perhaps, other ideas.

But it is to be noted that phenomenalism as we have defined it also has a methodological side as best represented by Descartes. Once it has been noted that the immediate objects of our awareness are sensations and one wishes to somehow distinguish between those sensations or ideas over which we have no control and which have a kind of permanence and at least seemingly are independent of us, and those over which we do have a kind of control and which are impermanent and are at least seemingly dependent on us, and all phenomenalists wish to do this, it is method that is called for. But the method clearly varies with the kind of phenomenalism involved.

The standard metaphysical thesis of phenomenalism represents a kind of ontological reductionism wherein the common sense realm of external material objects gives way to a world of sensations, sense data or ideas. It may best be expressed in the formal mode as the linguistic claim that all statements about material objects can be translated without loss of content into statements about sensations and the dispositions to have them. Thus ultimately all there really is in the world are our and other's ideas, sensations and certain dispositions and the souls (minds) that have these ideas, sensations and dispositions.

The ontological form commonly derives from an epistemological form of phenomenalism that claims that all that we can ultimately know are our ideas or sensations and through generalizations concerning them our dispositions to have certain ideas or sensations after having certain other ideas or sensations. This view has different origins. One is the argument, common in the seventeenth century, that sensations can bear no resemblance to their causes. On this view physico-chemical description and explanation is possible regarding the relationship between the external objects and the sense-organs, and of the manner in which the physico-chemical changes in the neural receptors are transmitted to the brain, and, in principle at least, of the resultant changes in the brain. But, it is maintained, our sensations are different in kind from the proposed physico-chemical states of the brain and so any explanation of a causal connection between them is impossible. The next step is to claim that since all our knowledge of the world rests on our sense experience, and since no explainable relation between our sensations and an external world is possible, we can have knowledge only of our sensations and their relationships with each other.

This form of the argument seems to rather blatantly presuppose what it says is impossible, viz., knowledge of an external world of material objects. There are, however, less objectionable forms of the argument for epistemological phenomenalism. It is, for instance, argued that a consideration of the relationships that exist among our sensations shows them to be private. When we look at, say, an envelope we find that it appears rectangular from one point of view and trapezoidal from another, or larger or smaller depending on our distance from it. Since only I can occupy my particular vantage point exactly at any moment in time, it follows, it is argued, that only I can have the sensations I am now having. This privacy, it goes on, precludes our having any knowledge of a public world of external objects. And since my sensations alone are not sufficient in themselves to guarantee the existence of external material objects (the problem of hallucinations, for instance, is being thought of) we cannot make any claims of the existence of "private" external material objects (if this is a meaningful concept to begin with). Within the context of this paper it is not necessary to concern ourselves with the validity or force of these arguments but only to determine to what degree they were held to be convincing by people like Isaac Newton and what effects on methodology such a belief could or should have.

What I wish to call methodological phenomenalism arises out of a belief in the truth of the premises of the first sort of argument for epistemological phenomenalism above which rests on a view concerning the physiology of perception, but also out of the additional belief that the conclusion of that argument can be circumvented through the following of certain rules of inquiry. The sorts of rules put forward and their justification can vary and have varied from one individual to another. For Descartes the principal rule is to suspend the operation of the will until understanding is achieved, while the justification involves the incongruity of the powers of the faculties of the will and understanding and the ultimate beneficence of God.

Having provided a rough map of what we have here called phenomenalism, our next task will be to locate Newton on that map, i.e., to determine what sort of phenomenalist he was if any, and to try and understand how he got there. I will attempt to do this by first trying to discover what ideas of method and epistemology Newton was concerned with in his early years (more specifically, 1661-1665) and to determine, in so far as is possible, where on the map he belonged in that period. This will be done by means of a manuscript of this period which will allow us to determine which books, outside the normal curriculum of Cambridge University, Newton was reading at that time. We will consider the possible influence of these works on Newton's epistemological views as revealed by this same manuscript as well as a slightly later one written sometime between 1666 and 1669. There will also be comparisons made of these early views with those of his later years as revealed by both published and unpublished materials. In this connection we will take up the issue of why that position did or did not change over the years. Finally, we will consider some of the ways in which our treatment of Newton puts his mature views in a new light and helps us to understand the inappropriateness of many of Berkeley's criticisms of Newtonian science.

NOTES

CHAPTER I

[1]Principally in Descartes' Meditations, Galileo's The Assayer, Hobbes' De corpore and Boyle's Origin of Qualities and Forms.

[2]The precis and what appears to be a letter (or note) from Newton, though not in his hand, regarding a proof in the Principia are among the Locke papers in the Bodleian Library (MS Locke c. 31, pl. 99).

[3]In Locke's Epistle to the Reader in his An Essay Concerning Human Understanding, ed. John W. Yolton (London: Everyman's Library, 1971), p. xxxv, he writes,

> The commonwealth of learning is not at this time without master-builders, whose mighty designs, in advancing the sciences, will leave lasting monuments to the admiration of posterity; but everyone must not hope to be a Boyle or a Sydenham; and in an age that produces such masters as the great Huygenius and the incomparable Mr. Newton, with some others of that strain, it is ambitious enough to be employed as an underlabourer in clearing ground a little, and removing some of the rubbish that lies in the way of knowledge . . .

[4]See Richard H. Popkin, "Berkeley and Pyrrhonism," Review of Metaphysics, vol. V (1951-52), pp. 223-46. It is interesting to note that the full title of the Principles is A Treatise Concerning the Principles of Human Knowledge,

<u>Wherein the chief causes of error and difficulty in the Sciences, with the grounds of Scepticism, Atheism, and Irreligion, are Inquired into</u>, and that of the <u>Dialogues</u> is <u>Three Dialogues Between Hylas and Philonous. The design of which is plainly to demonstrate the reality and perfection of human knowledge, the incorporeal nature of the soul, and the immediate providence of a Deity: in opposition to Sceptics and Atheists. Also to open a method for rendering the Sciences more easy, useful, and compendious</u>.

[5]See Galileo Galilei, <u>Two New Sciences</u>, trans. Stillman Drake, (Madison: University of Wisconsin Press, 1974), pp. 157-9. On pages 158-9 Salviati says,

> The present does not seem to me to be an opportune time to enter into the investigation of the cause of the acceleration of natural motion, concerning which various philosophers have produced various opinions, some of them reducing this to approach to the center; others to the presence of successively less parts of the medium [remaining] to be divided; and others to a certain extrusion by the surrounding medium which, in rejoining itself behind the moveable, goes pressing and continually pushing it out. Such fantasies, and others like them, would have to be examined and resolved, with little gain. For the present, it suffices our Author that we understand him to want us to investigate and demonstrate some attributes [<u>passiones</u>] of a motion so accelerated (whatever be the cause of its acceleration)...

It is also interesting to note that the theory of accelerated motion put forward by Sagredo was held by Galileo sometime between 1589 and 1592 when he wrote <u>De motu</u>; See Galileo Galilei, <u>On Motion and On Mechanics</u>, trans. and notes I. E. Drabkin and Stillman Drake, (Madison: University of Wisconsin Press, 1960), p. 89.

[6]Although it is often said that Galileo's law of falling bodies is deducible from Newtonian mechanics, this is not strictly true. What is deducible is a general law of which Galileo's law is a special case for small distances from the Earth. It should also be noted that Newton had speculated as to a mechanical cause of gravity in several places, e.g., Query 21 of the Opticks and many years earlier in the "Quaestiones quaedam philosophicae."

[7]Norwood Russell Hanson, "Galileo's Real Discoveries in Dynamics," in Homage to Galileo, ed. M. F. Kaplon, (Cambridge, Mass.: MIT Press, 1965), p. 46.

[8]The center for the discussion of the intensification and remission of qualities was Merton College. The principal figures involved were Thomas Bradwardine (c. 1290-1349), Richard Swineshead (or Suiseth, or the "Calculator") (fl. 1344-1350), William of Heytesbury (fl. 1338-9), and John of Dumbleton (fl. 1331-49). Amongst the products of their discussion was the discovery of the Merton Rule that the distance covered by a falling object was equal to one-half its final velocity times the time it had been falling ($s=\frac{1}{2}V_f t$).

[9]"Democritus Fr. 9, Sextus adv. Math. VII, 135 By convention are sweet and bitter, hot and cold, by convention is colour; in truth are atoms and the void. . . . (136) In reality we apprehend nothing exactly, but only as it changes according to the condition of our body and of the things that

impinge on or offer resistance to it." From G. S. Kirk and J. E. Raven, The Presocratic Philosophers, (Cambridge: Cambridge University Press, 1962), p. 422.

CHAPTER II

NEWTON AND HOBBES

During the period from 1661 to 1665, Newton's student years at Trinity College, Cambridge, and just preceding the *annus mirabilis* of 1665/1666, Newton was reading with great care six authors: René Descartes (*The Principles*, *Meteorology*), Galileo Galilei (*Dialogue on the Great World Systems*), Henry More (*The Immortality of the Soule*), Joseph Glanvill (*The Vanity of Dogmatizing*), Robert Boyle (*The Spring of the Air*, *History of Colours*, *History of Cold*) and Thomas Hobbes (*De corpore*). The influence of each of them was profound, but whereas much has been written of the influence of Descartes[1] and Boyle[2] very little has been made of the influence of the others. Yet in Newton's commonplace book of those student years, when, it will be argued, he was laying down those methodological and epistemological ideas that were, with very little change, to last him a lifetime, the influence of all of these men was central.

Thomas Hobbes (1588-1679) is generally thought to have had little influence on Newton since there are no references to him in Newton's published works and only the derogatory use of the term "Hobbist" is to be found in his extant letters.[3] A single direct reference does exist, however in the unpublished manuscript of "Quaestiones quaedam philosophicae" which forms a part (folios 87-135) of the commonplace book of 1661-1665 (Newton MSS Add. 3996), in which there are direct references to Boyle, Galileo, More, Glanvill and Descartes. If there is but this one reference how can it be maintained that Hobbes is a central figure in the formation of Newton's methodology and epistemology? This scarcity of direct reference is not in itself a good reason to think that Hobbes had little or no influence.

Isaac Newton was a most conservative man. In dress and manner he sought to stand out as little as possible from other men of his station. He had what has been considered by some scholars a pathological fear of public disagreement.[4] His particular religious beliefs (he was a Unitarian)[5] were kept secret throughout his life. His closest friend, Fatio de Duillier, was abandoned when arrested for religious fanaticism on the streets of London. In short, Newton was extremely cautious concerning any matter that might be taken to reflect on his character.[6] For such a man any outright alliance with Thomas Hobbes was unthinkable. By 1658 John Bramhall, Bishop of Derry (while an expatriate in Paris) had attacked Hobbes for impiety in the appendix to <u>Castigations of Hobbes's Animadversions</u>

entitled "The Catching of Leviathan the Great Whale." In the year 1666 a committee of the House of Commons was charged to consider a bill against "Atheism and Profaneness" and in this regard to examine the Leviathan. Just after Hobbes's death in 1679 an anonymous broadside appeared containing the following epitaph:

> Here lies Tom Hobbes, the Bug-bear of the Nation,
> whose Death hath frighted Atheism out of Fashion.[7]

Newton, who was secretive of his own religious beliefs and afraid of being branded a heathen, would certainly not link his name in any way with that of Hobbes. But it is interesting, on the other hand, that Hobbes was never attacked in print by Newton. Many of the men he most respected and befriended did after all launch open attacks on Hobbes and Hobbism. Henry More attacked Hobbes's materialism in his Immortality of the Soule of 1659, a book that Newton mentions in his "Quaestiones." Samuel Clarke, Newton's defender (and likely his spokesman) in the Leibniz - Clarke correspondence, defended absolute morality and free-will against Hobbes in his two series of Boyle Lectures (1704-1705). John Wallis, Savilian Professor of Geometry at Oxford University and frequent correspondent of Newton, attacked the mathematical demonstrations in Hobbes's De corpore in two works, Elenchus geometriae Hobbianae (1655) and Hobbius Heauton-timorumenos (1662). What is more, Newton probably supported the substance of these attacks, but he himself refrained from any involvment. This is made the more curious by the fact that Hobbes himself attacked both Wallis and, more importantly to this point, Robert Boyle in print.[8] Yet Newton still refrained. It seems plausible to me that he refrained out of a sense of respect for a man whose thought was important to his development, but, on the other hand, gave Hobbes no credit for his role out of a fear of being in any way identified with him.

Hobbes is mentioned in the "Quaestiones" which was part of a commonplace book meant for no one else's eyes but Newton's, and at a time when Hobbes's name was not yet anathema, but not again until Newton's breakdown of 1693, when he wrote John Locke on 16th September, saying,

> For I am now satisfied that what you have done is just & I beg your pardon for my having hard thoughts of you for it & for representing that you struck at ye root of morality in a principle you laid down in your book of Ideas [An Essay Concerning Human Understanding] & designed to pursue in another book & that I took you for a Hobbist.[9]

It is also very strange that all the books quoted or paraphrased by Newton in the "Quaestiones" are to be found in the catalogue of Newton's library[10] but two, and one is Hobbes's De corpore.[11] In fact, whereas thirty-two volumes of various works of Boyle and four volumes of Descartes are to be found in the catalogue, the only work by Hobbes is the innocuous Wonders of the Peak (London, 1678) a travel poem very much in vogue at the time. Leviathan and De corpore are made conspicuous by their absence.

The reference to Hobbes in the "Quaestiones" is to be found on folio 130r,

> Hobbs. part 4th chap 1st. Motion is never y^e weaker for y^e object being taken away for y^n dreams would not be so cleare as sence. but to men wakeing things past appear ob= [obscurer(?)] then things present because y^e organs being moved by other present objects at y^e same time those phantasms are lesse predominant.[12]

Although Newton does not tell us what work of Hobbes he is quoting or paraphrasing, it is easily established to be a paraphrased translation of the following lines from chapter xxv (which is the first chapter) of part IV of Hobbes's De corpore:

> . . . an motus remoto objecto debilior est? si esset, etiam phantasmata imaginantis minus essent clara quam in sensione, idque semper et necessario; quod non est verum. In somniis enim (eae autem dormientium sunt imaginationes) non minus clara sunt quam in sentiente. Vigilantium autem phantasmata rerum praeteritarum quam praesentibus objectis simul commota faciunt ut minus praedominentur.[13]

Which is translated in The English Works of Thomas Hobbes of Malmesbury, edited by Sir William Molesworth, as:

> Is the motion the weaker, because the object is taken away? If it were, then phantasms would always and necessarily be less clear in the imagination, than they are in sense; which is not true. For in dreams, which are the imaginations of those that sleep, they are no less clear than in sense itself. But the reason why in men waking the phantasms of things past are more obscure than those of things present, is this, that their organs being at the same time moved by other present objects, those phantasms are the less predominant.[14]

The importance, for our purposes, of this passage does not lie in its content[15] but rather in the fact that it enables us to establish that Newton was reading De corpore, and with some care, in the crucial period just preceding the annus mirabilis. It also leads us to look for other passages in the "Quaestiones" concerning the ideas of De corpore.

What appears to be the most crucial passage in the "Quaestiones" concerning Newton's thoughts on methodology and espistemology at the time are to be found on folio 101v. The passage is headed, "Philosophy," but there is another heading which is crossed out by a single line, "Occult Qualityes." The passage reads,

> The nature of things is more securely & naturally deduced from their operacōns one upon another ȳ upōn o^e senses. And when by y^e former experiments we have found y^e nature of bodys, by y^e latter wee may now clearly find y^e nature of o^e senses. But so long as wee are ignorant of y^e nature of both soule & body wee cannot clearely distinguish how far an act of sensation proceeds from y^e soule & how far from y^e body etc.[16]

When we look at part I, chapter 6 of De corpore we find the following passages:

> From this consideration of what is produced by simple motion, we are to pass to the consideration of what effects one body moved worketh upon another . . . . From which contemplation shall be drawn that part of philosophy which treats of motion.
>
> In the third place we must proceed to the enquiry of such effects as are made by the motion of the parts of any body, as, how it comes to pass, that things when they are the same, yet seem not to be the same, but changed. And here the things we search after are sensible qualities, such as light, colour, transparancy, opacity, sound, odour, savour, heat, cold, and the like; which because they cannot be known till we know the cause of sense itself, therefore the consideration of the causes of seeing, hearing, smelling, tasting, and touching, belongs to this third place . . . .[17]

and,

> Also the reason, why all these things are to be searched after in the order above-said, is, that

> physics cannot be understood, except we know first what motions are in the smallest parts of bodies; nor such motions of parts, till we know what it is that makes another body move; nor this, till we know what simple motion will effect. And because all appearance of things to sense are determined, and made to be of such and such quality and quantity by compounded motions, every one of which has a certain degree of velocity, and a certain and determined way; therefore, in the first place, we we [sic] are to search out the ways of motion simply (in which geometry consists); next the ways of such generated motions as are manifest; and, lastly, the ways of internal and invisible motions (which is the enquiry of natural philosophers).[18]

That it was in connection with his reading of De corpore that Newton wrote the crucial passage on folio 101v of the "Quaestiones" is, I believe, quite clear from the above. Newton's passage in this case, however, is somewhat more than a paraphrase or precis of the relevant passages of De corpore. It appears to take a position somewhat different in focus than that of Hobbes yet one that, like the Hobbesian notion, seeks the correct ordering of scientific inquiry. Newton seems to put more emphasis than Hobbes[19] on the problem of determining what distinct roles the object and the soul play in the act of perception and that not out of any apparent interest in the act of perception itself but as a means to discovering the nature of objects. For Newton sees that one of the principal problems of scientific inquiry is the problem of how to distinguish those qualities that are in the object from those apparent qualities that we, in the act of perception, contribute to the object. It is this problem, I will argue, that was central to Newton's thought on methodological and epistemological issues.

NOTES

CHAPTER II

[1]Alexandre Koyré, Newtonian Studies, (London: Chapman & Hall, 1965), pp. 53-114; see also John Herivel, The Background to Newton's Principia, (Oxford: Clarendon Press, 1965).

[2]L. T. More, The Life and Works of the Honourable Robert Boyle, (New York: Oxofrd University Press, 1944).

[3]See p. and n. 9 of this chapter.

[4]Consult, e.g., Frank E. Manuel, A Portrait of Isaac Newton, (Cambridge: Belknap Press, 1968), pp. 51ff.

[5]For an excellent discussion of Newton's Unitarianism see H. McLachlan, The Religious Opinions of Milton, Locke and Newton, (Manchester: Manchester University Press, 1941), pp. 117-172.

[6]See William Whiston, Memoirs of the Life and Writings of William Whiston, (London, 1749), pp. 292-4 on Newton's character; see also Manuel, Portrait.

[7]An Elegie upon Mr. Thomas Hobbes of Malmesbury, Lately Deceased, (London, 1679). [Broadside] The "Epitaph" of the elegy is reprinted by S. I. Mintz, "A Broadside

Attack on Hobbes," History of Ideas News Letter, I (1955) : 19-20.

[8]Although there is little or no evidence of Newton's relationship with Boyle prior to 1673 it is quite clear that Newton held him in high regard from the period of the commonplace book of 1661-1665 till the end of his life. There was a long and, for Newton, intimate correspondence relating to chemical matters. There were occasional meetings beginning in the Spring of 1675 (mentioned by Newton in a letter to Oldenburg dated 14th, December 1675; item 147 in The Correspondence of Isaac Newton edited by H. W. Turnbull, vol. I, (Cambridge: Cambridge University Press, 1959), pp. 392-3). Further evidence of Newton's regard for Boyle is that he instructed Halley to give presentation copies of the Principia, upon publication, to the Royal Society, Mr. Boyle, Mr. Pagit and Mr. Flamsteed (mentioned in a letter from Halley to Newton dated 5th, July 1687; item 309 in The Correspondence of Isaac Newton, vol. II, (Cambridge: Cambridge University Press, 1960), pp. 481-2.).

[9]Item 421, letter from Newton to Locke, dated, 16th, September 1693, The Correspondence of Isaac Newton, vol. III, (Cambridge: Cambridge University Press, 1961), p. 280.

[10]The catalogue of Newton's library used here is the compilation of the Dr. James Musgrave Catalogue discovered by R. de Villamil and the "Huggin's List" in the British Museum, which compilation appears in R. de Villamil, Newton: The Man, (London: Knox, [no date, though 1931]), pp. 62-111.

[11]The other is Joseph Glanvill's _Vanity of Dogmatizing_.

[12]Newton manuscript, "Quaestiones quaedam philosophicae," part of the commonplace book of 1661-1665, University Library, Cambridge, England (Add. 3996 folios 87r-135r), folio 130r.

[13]Thomas Hobbes, _Hobbes' Latin Works_, ed. Sir William Molesworth, (London: Bohn, 1839), vol. I, p. 323.

[14]Thomas Hobbes, _The English Works of Thomas Hobbes of Malmesbury_, ed. Sir William Molesworth, (London: Bohn, 1839), vol. I, p. 396.

[15]Newton in fact goes on to show that there are complications that arise from Hobbes's thesis, viz., that on Hobbes's account we should never forget anything and that since many different motions causing present and past phantasms would be of the same strength at any given moment of time, "we should thinke of an immense multitude of objects at once."

[16]Newton, "Quaestiones," folio 101v.

[17]_Hobbes' English Works_, pp. 71-2. The Latin text of which is as follows:

> Post considerationem eorum quae fiunt ex motu simpliciter, sequitur consideratio eorum, quae motus, unius corporis efficit in corpus aliud . . . ex qua contemplatione existet philosophia pars illa quae de motu est. . . . Tertio loco ad eorum inquisitionem devenietur quae fiunt ex motum partium, ut in quo consistit quod eaedem res, sensui tamen eaedem non videantur sed mutatae; itaque investigantur hoc loco, qualitates sensibiles, quales sunt, _lux_. _color_, _diaphaneitas_, _opacitas_, _sonus_, _odor_, _sapor_, _calor_, _frigus_, et _similia_, quae _quia_ sine cognitione causae _ipsius_ sensionis cognosci non possunt, consideratio causarum _visionis_, _auditus_, _olfactus_, _gustus_, et _tactus_,

tertium locum obtinebit . . .

From Hobbes' Latin Works, vol. I, pp. 63-4.

[18]Ibid., p. 73. The Latin text of which reads as follows:

> Haec autem omnia eo ordine quem dixi investiganda esse, ex eo constat quod physica intelligi non possunt nisi cognito motu qui est in partibus corporum minutissimis, neque talem motum partium nisi cognito quid sit quod motum efficit in alio, neque hoc nisi cognito motus simpliciter quid efficiat. Et ex eo quod omnis rerum ad sensus apparitio determinatur, talisque et tantus fit, per motus compositos, quorum unusquisque certum gradum velocitatis, certamque viam obtinet; primo loco, viae motuum simpliciter (in quo consistit geometria) deinde viae motuum generatorum et manifestorum, postremo viae motuum internorum et invisibilium (quas quaerunt physici) investigandi sunt.

From Hobbes' Latin Works, vol. I, pp. 64-5.

[19]Hobbes's interest seems to have been focused on how objects cause our sensations rather than on what consequences follow for scientific inquiry from the fact that they do, although he was aware that there were such consequences and mentions some of them.

CHAPTER III

NEWTON AND DESCARTES

Reading Descartes

Newton's familiarity with the problem of which qualities do and do not belong to objects perceived did not stem from his reading of Hobbes alone. Descartes, Galileo, More, Boyle and Glanvill, all of who's work he was reading during the period of the commonplace book, deal with the problem with varying degrees of sophistication, and there can be very little doubt that it was through their eyes that he first saw the problem. The "problem" as discussed by the men mentioned above was only rarely defined and for the most part consisted of a plethora of different, though related, issues.

There are eight folios containing explicit references to Descartes ("Cartes" or "Des-Cartes") in the "Quaestiones." These references occur at folios 93v, 95v, 96v, 100v, 110r, 110v,111r and 117r. Each of them involves a reference to either The Principles of Philosophy or the Meteorology. Both of these works were in Newton's library although the Musgrave-Huggins' List does not contain an entry for the Meteorology. The list does contain the entry, "Descarte's Principia Philosophiae, 4to. 1656."[1] The shelf-list of the Newton Library of Trinity College Library, Cambridge, contains no entry for the Principles but does contain the entry, "NQ.9.116 Descartes (R.). Opera philosophica. Ed. 3^d^. 4^0^ Amsterdami 1656." This volume does not have a title page identifying it as Descartes' Opera philosophica. It begins instead with the title page of the first work which it contains, Principia philosophiae. It is apparent then that this is the same book listed in the Musgrave-Huggins' List and that Newton had in his library far more of Descartes' work than one would be led to believe by that list. The Opera contains: Principia philosophiae, Dissertatio de methodo, Dioptrice, Meteora, Passiones animae, Meditationes de prima philosophia, Obiectiones, Rationes Dei, and Epistola Renati Des Cartes ad celebrrimum virum D. Gisbertum Voetium.

There are very few notes by Newton in the book. Against the title "Obiectiones Secundae" Newton has written "per Mersennum."[2] A line is crossed out on p. 91 of the Principles. There are no notes in the Principles but part III is particularly dirty and ink stained. Others of the "Obiectiones & Responsio" are identified in a printed hand--perhaps Newton's. There are no other notes in the book.

We can be fairly certain that Newton read the Principles during the period of the "Quaestiones," for it contains two explicit references to it. On folio 93v, Newton writes, "Whither ☉ move y^e^ vortex about, as Des-Cartes [illegible] by his beames. pag 54 Princip Philos: partis 3." Newton translates and cites a part of part II of the Principles on folio 117r of the "Quaestiones."

> Cartes defines motion 2â pte Pr: Ph: to be The Translation of one part of matter or one body from y^e^ vicinity of those bodys w^ch^ imediatly touch it & seem to rest, to y^e^ vicinity of others.

This is a translation of a part of Principle XXV which part, in the Haldane and Ross translation, reads,

> . . . motion . . . is the transference of one part of matter or one body from the vicinity of those bodies that are in immediate contact with it, and which we regard as in repose, into the vicinity of others.[3]

It can similarly be established that Newton read Descartes' Meteorology and that he paraphrases it extensively in the "Quaestiones." On folio 110v, headed, "Of Meteors," Newton writes, "Whither fierce winds dry bodys by beating out y^e^ moist [ure] from other bodys Cartes Met:." While on folio 111r, he writes, "Raw [?] oyle or spirits of salt (so sharpe y^t^ they will disolve gold) is extracted out of salt. Cartes Met: of Salt." In the "Third Discourse," which is titled, "Of Salt," of the Meteorology, we find,

> And following this we can understand the nature of that extremely acrid and strong water which can corrode gold, and which the alchemists call spirit or oil of salt. For inasmuch as it is extracted only by the violence of a very hot fire, either from pure salt, or from salt, mixed with some other very fixed and dried body . . . .[4]

All the material from the "Quaestiones" that I have been able to trace to the <u>Meteorology</u> is summarized in table 1.

TABLE 1

THE SOURCES IN THE METEOROLOGY OF PASSAGES IN THE "QUAESTIONES"

"QUAESTIONES"		METEOROLOGY
FOLIO	LINE(S)	PAGE(S)*
96v	1	267
96v	5	273
100v	1-2	275-276
100v	11	277
100v	28	277
100v	28-29	268
100v	31	276
100v	32-33	280
100v	34-35	279
100v	36-37	279
100v	37-38	281
111r	1	281
111r	2-3	282-283
111r	3-4	284-285
111r	5-6	285
111r	7-8	285
111r	9-10	285-286

*Page references are to the Olscamp edition.

Although there are far more notes from the Meteorology than from the Principles in the "Quaestiones," the latter work is infinitely richer in its epistemological content and it is with it that we will be concerned.

The Influence of Descartes

In the Principles Descartes distinguishes between two kinds of sensations; those that can be properly attributed to bodies, and those that should not be so attributed.[5] All those that can be so attributed are diverse modes of extension, e.g., figures, the situation of parts, and their movement and, of course, extension itself. Those that cannot (should not) be so attributed are " . . . all the sensations such as pain, pleasure, light and colour, sounds, odours, tastes, heat, hardness, and all other tactile qualities."[6]

We can, of course, have knowledge of our sensations but only in so far as we do not attempt to go beyond them to their existence in external bodies.[7] Thus " . . . we have a clear or distinct knowledge of pain, colour, and other things of the sort when we consider them simply as sensations or thoughts. But when we desire to judge of such matters as existing outside our mind, we can in no wise conceive what sort of things they are."[8] Which is to say that we can have no clear and distinct idea of what sort of things they are. The matter is different in the case of magnitude, figure, etc., as Principle LXIX of part I indicates.

> This will be more especially evident if we consider that size in the body which is seen, or figure or movement, . . . or situation, or duration, or number, and the like, which we clearly perceive in all bodies, . . . are known by us in a quite different way from that in which colour is known in the same body, or pain, odour, taste, or any of the properties which . . . should be attributed to the senses. For although in observing a body we are not less assured of its existence from the colour which we perceive in its regard than from the figure which bounds it, we yet know this property in it which causes us to call it figured, with much greater clearness than what causes us to say that it is coloured.[9]

When we say that we perceive colors in objects then, we should be understood to mean that there is in the object something "of whose nature we are ignorant" but which has caused a "clear and vivid sensation" in us.[10]

Two things, then, happen when we perceive objects; we have various sensations and at the same time "the mind . . . perceives magnitudes, figures, movements and the like, which . . . [are] . . . exhibited to it not as sensations but as things or the modes of things existing."[11] Since magnitudes, figures, movements and the like are clearly and distinctly perceived as the modes of things existing they can be known to exist in external bodies (if the external bodies are known to exist, which is a separate problem). Our sensations, however, when considered as existing in external bodies lead to unclear and indistinct ideas and so cannot be known as existing in external bodies. If this fact is ignored we " . . . allow ourselves to fall into the error of holding that what we call colour in objects is something entirely resembling the colour we perceive, and then supposing that we have a clear perception of what we do not perceive at all."[12]

Thus if external bodies do exist (and the grounds for saying that they do have not yet been given) we can know that they are extended, have figure and magnitude, etc., since we can form clear and distinct ideas of their having such attributes on the basis of our perceptions. We can also know that the bodies having those attributes are the causes of our sensations of taste, smell, sight, etc., but since we can form no clear and distinct ideas of what attributes in these external bodies are causing these sensations we cannot have knowledge of those attributes on the basis of our sensations.

We can now state what Descartes maintains are the grounds for our knowledge of the existence of external objects and that is that it is of the nature of God that He is not a deceiver.

> . . . inasmuch as we perceive, or rather are stimulated by sense to apprehend clearly and distinctly a matter which is extended in length, breadth, and depth, the various parts of which have various figures and motions, and give rise to the sensations we have of colours, smells, pains, etc., if God immediately and of Himself presented to our minds the idea of this extended matter, or merely permitted it to be caused in us by some other object which possessed no extension, figure, or motion, there would be nothing to prevent Him from being regarded as a deceiver. For we clearly apprehend this matter as different from God, or ourselves, or our mind, and appear to discern very plainly that the idea of it is due to objects outside of ourselves to which it is absolutely simi-

> lar. But God cannot deceive us, because deception is repugnant to His nature . . .[13]

A "perfect science" then is one that proceeds from our knowledge of God's nature to the " . . . explanation of the things which He has created, and if we try from the notions which exist naturally in our minds to deduce it, for in this we shall obtain a perfect science, that is, a knowledge of the effects through their causes."[14]

Since Newton's interest is primarily in the issue of how the qualities of external objects are to be determined he must have looked quite closely as Descartes' account in the Principles. But little more is said in the Principles regarding this issue than what I have summarized above and this does not seem terribly satisfactory. Ultimately, here as elsewhere in the Cartesian doctrine, the criterion of the real and true is the clarity and distinctness of the ideas that we have of them. The qualities of external bodies are the causes of our experience of those bodies, but only some of those causes "resemble exactly" the experience that they produce. The remainder of our experience is caused by what Descartes variously describes as something of whose nature we are absolutely ignorant,[15] something that we know with very little clearness,[16] something that we do not perceive at all.[17] The application of the criteria of clarity and distinctness, in this case at least, seems rather uncertain and must surely have seemed unsatisfactory to the demanding Newton.

Newton was certainly not content with the use of clarity and distinctness as the criteria serving to distinguish real qualities from pseudo qualities, for their use implied that ultimately knowledge did not rest upon sensation but upon ratiocination, since our knowledge of external objects derives from our innate (and thereby clear and distinct) concepts of extension, motion, number, etc. It is these ideas which are products of God's nature for it is God who provided us with them. Sensation is not the ground of such knowledge; we are merely " . . . stimulated by sense to apprehend clearly and distinctly a matter which is extended in length, breadth, and depth . . . ."[18]

The matter is further complicated by the physiological factors that Descartes brings into the problem of perception in part IV of the Principles.

The motions of various particles in the world produce motions in our nerves when they come in contact with our bodies. This motion in the nerves is transmitted by the nerves to the brain.

> . . . the movements which are thus excited in the brain by the nerves, affect in diverse ways the soul or mind, which is intimately connected with the brain, according to the diversity of the motions themselves. And the diverse affections of our mind, or thoughts that immediately arise from these motions, are called perceptions of the senses, or in common language, sensations.[19]

Descartes then draws our attention to the fact that the same motions in our brains can be produced by various causes. In Principle CXCVI he tells of the phantom limb phenomenon[20] and in Principle CXCVIII, he writes,

> . . . if we receive a blow in the eye hard enough to cause the vibration to reach the retina, we see myriads of sparks which are yet not outside our eye; and when we place our finger on our ear to stop it, we hear a murmuring sound whose cause cannot be attributed to anything but the agitation of the air which is shut up within it.[21]

Thus does our physiology lend itself to deception on the Cartesian account.

Newton, nevertheless, did accept in part the Cartesian account of perception. That he did so is made clear by folio 130v of the "Quaestiones" in which Newton has adopted the view that external objects cause motions within our sensory organs, which motion is transfered by the nerves to the brain. The motion of the brain thus produced in some sense <u>is</u> a representation of the external object (within the restrictions imposed by the distinction between those qualities that belong to the object and those that belong to sense), and it is this representation that is seen by the mind (soul).

> Of y^e Soule
>
> Memory is a faculty of y^e soule (in some measure) for else how can divers sounds, or words excite her to divers thoughts - or 3 4 5 or more words beget y^e same thoughts in her. Perhaps shee remembers by y^e helpe of characters in y^e Braine, but then how doth she remember y^e signification of those characters.
>
> Quae 1 Why objects appeare not invert, Resp: The mind or soule cannot judge y^e image in y^e Braine to be inversed unlesse shee perceived externall things- w^{th} w^{ch} shee might compare y^t Image:
>
> 2. Why doe appeare to bee w^{th}out our body? -Resp: Because y^n in y^e image of things delineated in the braine by sight, y^e bodys image is placed in y^e midst of y^e images of other things, is moved at o^e

command toward & from those other images, etc:
3. But why are not these objects then judged to bee in the braine Resp: Beacuse y^e image of y^e braine is not painted there, nor is y^e Braine perceived by y^e soule it not being in motion & probably soule perceives noe bodys but by y^e helpe of their motion. But were y^e Braine perceived together w^{th} those images in it wee should thinke wee saw a body like the braine encompassing & comprehending our selves y^e starrs & all other visible objects. etc:[22]

Newton apparently never gave up this theory of perception for in 1706 he included Query 28 in the Latin edition (and all future editions) of the Opticks, part of which reads,

> Is not the Sensory of Animals that place to which the sensitive Substance is present, and into which the sensible Species of Things are carried through the Nerves and Brain, that there they may be perceived by their immediate presence to that Substance? And these things being rightly dispatch'd, does it not appear from Phaenomena that there is a Being incorporeal, living, intelligent, omnipresent, who in infinite Space, as it were in his Sensory, sees the things themselves intimately, and throughly perceives them, and comprehends them wholly by their immediate presence to himself: Of which things the Images only carried through the Organs of Sense into our little Sensoriums, are there seen and beheld by that which in us perceives and thinks.[23]

Why should we maintain that the mystery of which qualities are real and which pseudo would so much interest Newton while the mystery of how motions in the brain are perceived as sensations would not? The answer is simply that Newton was more a physical scientist than a philosopher or psychologist. The issue of which qualities are real is for him the issue of which qualities may be used in the construction of explanations of phenomena, and these, clearly, are the qualities we shall term "primary." The issue of how these qualities give rise to the sensations that they do is really irrelevant to physics. Consider the phenomenon of a bar of iron glowing red when heated for a time in a fire. We can ask what makes it glow red. But the issue here is not how do we have a red sensation, it is why the heating of the bar produces a light that happens to cause (or be the occasion of) our seeing red. In this way the explanation of the relation between external objects and what they cause us to see was irrelevant to Newton[24] but the issue of what qualities were out there in the object was not. I am not maintaining that Newton had formulated these different issues or was aware of their relationship during the period of the "Quaestiones," but that his later thought had its origin in the authors and problems with which he was grappling in that period is certain. It is interesting to note in this regard that even the 1730 edition of the Opticks, the last edition to have been corrected by his own hand, contains no explanation of, nor query on, the operation of the sensorium. It was enough to take the mechanical explanation so far as the brain. In all editions of the Opticks, however, he made use of the distinction between real qualities and pseudo qualities, the distinction that Boyle, and Locke following him, were to call the primary-secondary quality distinction. Although Newton never clearly formulates the distinction, it is obviously presupposed in various passages. After Proposition II, Theorem II of the Opticks, the following Definition is given:

> The Homogeneal Light and Rays which appear red, or rather make Objects appear so, I call Rubrifick or Red-making; those which make Objects appear yellow, green, blue, and violet, I call Yellow-making, Green-making, Blue-making, Violet-making, and so of the rest. And if at any time I speak of Light and Rays as coloured or endued with Colours, I would be understood to speak not philosophically and properly, but grossly, and accordingly to such Conceptions as vulgar People in seeing all these Experiments would be apt to frame. For the Rays to speak properly are not coloured. In them there is nothing else than a certain Power and Disposition to stir up a Sensation of this or that Colour. For as Sound in a Bell or musical String, or other sounding Body, is nothing but a trembling Motion, and in the Air nothing but that Motion propagated from the Object, and in the Sensorium 'tis a Sense of that Motion under the form of Sound; so Colours in the Object are nothing but a Disposition to reflect this or that sort of Rays more copiously than the rest; in the Rays they are nothing but their Dispositions to propagate this or that Motion into the Sensorium, and in the Sensorium they are Sensations of those Motions under the Forms of Colours.[25]

Unfortunately Newton has very little more to say in the "Quaestiones" concerning these aspects of the Cartesian position, although he does put forward various criticisms of Descartes' views on extension, the vacuum, and atoms[26] which are related, albeit indirectly, to the problem here under consideration. But we shall later consider another early manuscript of Newton's, "De gravitatione et aequipondio fluidorum,"[27] that very likely dates from the period 1666-1669, immediately after the "Quaestiones," but preceeding the Letters on Opticks and the publication of the Principia, that takes up once again the task of criticizing the Cartesian position in a quite startling manner.

We turn now to a consideration of the possible influence of the writings of Galileo on the methodological and epistemological thought of Newton prior to 1666, and once again our primary source regarding this matter is the "Quaestiones."

NOTES

CHAPTER III

[1]Villamil, Newton: The Man, p. 74.

[2]Rene Descartes, "obiectiones," Opera philosophica (Amsterdam, 1656), p. 63.

[3]Rene Descartes, The Philosophical Works of Descartes, trans. E. S. Haldane and G. R. T. Ross (New York: Dover Publications, 1931), vol. I, p. 266.

[4]Rene Descartes, Discourse on Method, Optics, Geometry, and Meteorology, trans. Paul J. Olscamp (New York: Bobbs-Merrill, 1965), pp. 285-6.

[5]The Philosophical Works of Descartes, vol. I, part I, Principle XLVIII, p. 238.

[6]Ibid., part I, Principle XLVIII, p. 238.

[7]Ibid., part I, Principle LXVI, p. 247.

[8]Ibid., part I, Principle LXVIII, p. 248.

[9]Ibid., part I, Principle LXIX, p. 248.

[10]Ibid., part I, Principle LXX, p. 249.

[11]Ibid., part I, Principle LXXI, p. 250.

[12]Ibid., part I, Principle LXX, p. 249.

[13]Ibid., part II, Principle I, p. 254.

[14] *Ibid.*, part I, Principle XXIV, p. 229.

[15] *Ibid.*, part I, Principle LXVIII, p. 248.

[16] *Ibid.*, part I, Principle LXIX, p. 248.

[17] *Ibid.*, aprt I, Principle LXX, p. 249.

[18] *Ibid.*, part II, Principle I, p. 254. See also p. 11 above.

[19] *Ibid.*, part IV, Principle CLXXXIX, pp. 289-90.

[20] *Ibid.*, part IV, Principle CXCVI, pp. 293-4.

[21] *Ibid.*, part IV, Principle CXCVIII, p. 295.

[22] "Quaestiones," folio 130v. Folios 109r and 125r are also interesting in this regard. Newton describes various after images after having looked at the sun. When the effects had appeared to end he closed his eyes and imagined the sun. Upon opening his eyes he found that the after images had returned. It was as if, " . . . I had newly looked on y^e Sunne whence I gather y^t my Phantasie & y^e ☉ had y^e same operation uppon y^e spirits in my optick nerve & y^t y^e same motions are caused in my braines by both."

[23] Isaac Newton, *Opticks*, (New York: Dover Publications, 1952), p. 370. Query 28 originally appeared in the 1706 Latin translation edition of Samuel Clarke. It appeared next in the second English edition (1717), where it was numbered 28, and in all subsequent editions. The Dover Publications edition quoted above is taken from the fourth edition of 1730. It is useful in this regard to also look at Samuel Clarke's first letter of reply in the Leibniz-

Clarke Correspondence, a letter which Newton very likely helped compose,

> . . . that . . . the mind of man, by its immediate presence to the pictures or images of things, form'd in the brain by the means of the organs of sensation, sees those pictures as if they were the things themselves . . . Sir Isaac Newton considers the brain and organs of sensation, as the means by which these pictures are formed: but not as the means by which the mind sees or perceives those pictures, when they are formed.

The above is quoted from H. G. Alexander's edition of The Leibniz-Clarke Correspondence, (Manchester: Manchester University Press, 1956), p. 13.

[24]This is not to say that this problem had no bearing on Newtonian epistemology (for, as will be shown later, it did), but that this problem did not enter into the business of actually constructing scientific explanations (although it does bear on the issue of what things require explanation).

[25]Opticks, pp. 124-5.

[26]The folio or folios of the "Quaestiones" containing criticisms of Descartes' views on extension are 89r, on the vacuum 89r&v and 119v, on atoms 88r&v, 89r&v and 120r.

[27]Translated and published with the Latin text in Unpublished Scientific Papers of Isaac Newton, eds. A. R. Hall and M. B. Hall (Cambridge: Cambridge University Press, 1962).

CHAPTER IV

NEWTON AND GALILEO

Reading Galileo

There is only one direct reference to Galileo in the "Quaestiones," that on folio 121v, where Newton writes, "According is Galileus a iron ball of 100 Florentine (y^t is $78^{l.}$ at London Adverdupois weight) descends an 100 braces Florentine or cubits (or 49,10 Ells, perhaps 66^{yd}) in 5" of an hower."

The Musgrave-Huggins' List of Newton's library contains only one volume by Galileo, De systematae mundi, in the 1699 edition. But the statement quoted above, dating from between 1661 and 1665, clearly does not refer to this volume. The reference is, however, to another edition of Galileo's Dialogue on the Great World Systems. During the period 1661-1665 several editions were available, including the first English translation of the great work. This was one of a group of translations by Thomas Salusbury published in 1661 under the title, Mathematical Collections and Translations in Two Tomes.[1] The first item in the table of contents is, "I. Galileus Galileus, his

Systeme of the World: in Four Dialogues." Among the other items are works of Kepler and Foscarinus. In the Salusbury translation we find the following quote from Salviati in Dialogue II:

> I have both: and when we shall handle the business of motions apart, I will communicate them: in the interim, that we may have no more occasions of interrupting our discourse, we will suppose, that we are to make our computations upon a ball of Iron of a hundred (a) pounds, the which by reiterated experiments descendeth from the altitude of an hundred (b) yards, in five second-minutes of an hour.[2]

To which the footnotes, (a)(b), appear in the margin,

> (a)(b) Note that these Calculations are made in <u>Italian</u> weights and measures. And 100 pounds <u>Haverdupoise</u> make 131 l. <u>Florentine</u>. And 100 English yards makes 150 2/5 Braces <u>Florent</u>. So that the brace or yard of our <u>Author</u> is 3/4 of our yard.[3]

A Latin translation of the <u>Dialogue</u> by Mathias Berneggerus had appeared in 1635 and again in 1663. The corresponding passage in this edition is,

> Interim ut praecidatur occasio, colloquii filum amplius interrumpendi, ponamus, calculo nostro subjiciendum globum ferreum centum librarum, qui, quod experientia saepe repetita docuit, centum cubitorum altitudinem, quinq; secundis horae minutis emetitur.[4]

In comparing these two versions of the passage with Newton's in the "Quaestiones" several points emerge. Salusbury mentions Florentine "braces" and "pounds" but not "cubits," whereas Newton mentions all three. Both Newton and Salusbury have included a calculation of the equivalence between the English and Florentine measurements.[5] Their calculations, though different, are consistent with each other with the exception of what is probably a typographical error in the Salusbury version. He tells us that " . . . the brace or yard of our Author is 3/4 of our yard." By his own calculations the figure should have been 2/3.[6]

The Berneggerus translation mentiones neither the measurements being Florentine nor braces or yards, but rather, cubits. Both Berneggerus and Salusbury write of five second minutes of an hour, while Newton writes, " . . . 5" seconds of an hower."

John Herivel in his The Background to Newton's Principia, expresses his indebtedness to H. W. Turnbull for pointing out that certain figures in two early manuscripts of Newton were from Galileo's Dialogue and " . . . most probably from p. 200 of Salusbury's translation."[7] I think that we can now establish that Newton did use the Salusbury translation.

In the passage quoted above Salusbury set 100 yards equal to 150 2/5 braces which is 23.9" to the brace. This is an unusual figure, the one ordinarily used being 20" to the brace. Newton set 66 yards equal to 100 braces which yields 23.8" to the brace, close enough, given the kind of calculations involved, to be considered the same figure. In Newton's Vellum Manuscript[8] of 1665-1666 he again quotes Galileo's figure of 100 cubits in 5 seconds but more importantly he also writes, "Secundam Galilil.

caderet 4 cubits _id est_ 3 yds in 1 second." Now this latter figure is not the 23.8" brace or cubit of the same manuscript but a brace or cubit of 27" which is even further from the correct figure of 20". How can we account for this error? Newton had naturally assumed that the statement in the Salusbury edition that " . . . the Brace or yard of our _Author_ is 3/4 of our yard." was consistent with the figures that yielded a 23.8" brace. Using the Salusbury error as an equation Newton had,

1 brace = 3/4 yard

multiplying both sides by 4, he had,

4 braces or cubits = 3 yards.

And so he was misled by what was apparently a typographical error in the Salusbury edition. Since there appears to be no other reason for exactly this inconsistency in Newton's figures, it seems very nearly certain that Newton used the Salusbury edition of Galileo's _Dialogue_. It is possible, given the features of both the Berneggerus and Salusbury versions included in the Newton passage, that Newton read both along side each other, perhaps checking one against the other.[9] But in any case, it seems certain that Newton had read Galileo's _Dialogue on the Great World Systems_ prior to 1666 in the Salusbury edition.

The following discussion of what Newton found there is therefore based upon this edition published in 1661.

The Influence of Galileo

The aspect of the Dialogue with which we will be concerned is the epistemological and methodological thought of Galileo and what influence it might have had on Isaac Newton when he read it sometime during the period from 1661 to 1665. The Dialogue deals with the arguments leveled against the Copernican system. These were based on Aristotelian principles and on the evidence of experience. The Earth does not "appear" to move. Objects consisting of the four elements do "appear" to move in straight lines perpendicular to the Earth's surface. Galileo's consideration of the specific criticisms of Copernicanism takes place in a general framework of a discussion of the relation of experience to knowledge, and it is this that we will consider in relation to Newton.

From early in Dialogue I Simplicio continually opposes Salviati's Copernicanism with references to experience.

> SIMPL. . . . holding in all his [Aristotle's] argumentations, that sensible experiments were to be preferred before any reasons founded upon strength of wit, and said those which should deny the testimony of sense deserved to be punished with the loss of that sense . . .[10]

And again,

> SIMPL. Certainly, if you in this manner deny not onley the Principles of Science, but manifest Experience, and the Senses themselves, you can never be convinced or removed from any opinion which you once conceit . . .[11]

The key to Galileo's objections to the arguments advanced by Simplicio lies in his use of the term "manifest experience."[12] Salviati, who is generally considered to reflect Galileo's views, takes great pains throughout the Dialogue to show that experience is rarely manifest. Experience almost always requires interpretation. It is not merely seeing, but informed seeing that is necessary for science.

> SALV. It is not enough, Sagredus, that the subjects be noble and great, but the businesse consists in handling it nobly. And who knoweth not, that in the dissection of the members of a beast, there may be discovered infinite wonders of provident and prudent Nature; and yet for one, that the Anatomist dissects, the butcher cuts up a thousand.[13]

For the Newton of the "Quaestiones" things are rarely the way they seem; both the Sun and an exertion of the imagination could bring about the same set of sensations, and all our sensations were a product of an interaction between the soul and the external world. But even if the primary-secondary quality distinction could undercut these problems of perception, Galileo had found a new ground for concern.

In Dialogue II (pages 120-2) Salviati and Simplicio construct an argument for the non-rotation of the Earth. If a stone is dropped from the ceiling within a high tower and it is observed that the stone does not hit against the walls but falls parallel to them, then the Earth does not rotate. For if the Earth rotated the stone could not fall perpendicularly. The argument can be reformulated as follows:

A. If the Earth rotates, the body cannot fall perpendicularly.

B. But the body does fall perpendicularly.

therefore,

C. The Earth does not rotate.[14]

Salviati, after getting Simplicio to accept this argument, then argues that it is really a paralogism. The minor premise (B) presupposes the conclusion in the sense that what we see (the stone not hitting the walls of the tower) is an indication that the stone falls perpendicularly only if we assume that the tower (and thus the Earth) is not moving. And, since this is the conclusion that is claimed to follow from the premises, the argument is flawed by a petitio principi. We do not "see" the stone fall perpendicularly to the Earth though we do see it fail to hit the walls of the tower.

Not content with showing that the simple minded Simplicio can misinterpret experience without his realizing that he is interpreting anything, Galileo goes on to show that the quick witted Sagredo can make the same mistake, albeit in a more sophisticated way.

> SAGR. Touching the simple motion towards the centre dependent on the gravity, I think that one may confidently, without error, believe that it is by a right line, as it would be, were the Earth immoveable.
> SALV. As to this particular, we may not onely believe it, but experience rendereth us certain of the same.
> SAGR. But how doth experience assure us thereof, if we never see any motions but such as are composed of the

> two, circular and descending.
> SALV. Nay rather Sagredus we onely see the simple motion of descent; since that other circular one common to the Earth, the Tower and our selves remains imperceptible, and as if it never were, and there remaineth perceptible to us that of the stone, onely not participated by us, and for this, sense demonstrateth that it is by a right line, ever parallel to the said Tower, which is built upright and perpendicular upon the Terrestrial surface.[15]

Simplicio did not see motion perpendicular to the Earth but Sagredo did, while Simplicio thought that he did and Sagredo thought that he did not. But the apparent paradox is removed by the fact that Simplicio began by assuming the Earth did not move while Sagredo assumed that it did. Thus the difference in Salviati's (Galileo's) description of their respective experiences depends upon their different presuppositions. Once again the point is that the experience is not manifest; it is dependent upon the correct interpretation.

In order finally to drive home this point we are presented with the bewildered Simplicio saying,

> But for Gods sake, if it move transversly, how is it that I behold it to move directly and perpendicularly? This is no better than the denial of manifest sense; and if we may not believe sense, at what other door shall we enter into disquisitions of Philosophy?[16]

It is indeed a denial of manifest sense but not in the sense that Simplicio means. Galileo simply has Salviati state the interpretation of the experience which makes it relevant to the philosophical point at issue.

> In respect to the Earth, to the Tower, and to our selves, which all as one piece move with the diurnal

> motion together with the stone, the diurnal motion is as if it never had been, and becometh insensible, imperceptible, and without any action at all . . .[17]

Galileo approaches the relationship between experience and knowledge in another way which has misled some scholars into thinking him a believer in the Platonic theory of anamnesis.[18]

Seeking to convince Simplicio that the Earth reflects more light than the Moon, Salviati claims, "The cause for which you repute the Earth unapt for illumination, may rather evince the contrary: And would it not be strange, Simplcius, if I should apprehend your discourses better than you yourself?"[19]

Salviati begins by asking a question about Simplicio's experience, viz., " . . . when the Moon is near the Full, so that it may be seen by day, and also at midnight, at what do you think it more splendid, by day or by night?"[20] Simplicio answers, "By night, without all comparison."[21] And describes how he has seen the Moon in the day among the clouds and no brighter than them. Then Salviati asks a question concerning the interpretation of the experiences described by Simplicio, " . . . do you believe that the Moon is really more shining in the night than day, or that by some accident it seemeth so?"[22] Simplicio answers that it shines in the day the same as in the night and that it is in comparison with the dark night sky that it seems brighter at night. Salviati then points out to Simplicio that we never see the Earth lighted in the night, i.e., we have had no experience to refute the claim that the Earth shines more brightly than the Moon. If knowledge is to rest on experience, we must compare the experiences of Earth and Moon we have had, which is to say as seen in the daytime when both are illuminated. But Simplicio has already reported his experience of the white clouds around the daytime Moon shining as brightly as the Moon itself, and Salviati adds,

> . . . yea more, if you will but call to mind that you have sometimes seen some Clouds of vast greatness, and as perfect white as the Snow . . . . If therefore we were assured that the Earth is illuminated by the Sun, like one of those Clouds . . . it would be no less shining than the Moon.[23]

Sagredo then calls, Simplicio's attention to the fact that the Moon has risen and its brightness is less than the third reflection of the Sun's light upon a wall within a room. Salviati then makes the following Platonic sounding statement:

> Now, Simplicius, (if haply you be satisfied) you may conceive, as you your self know very well, that the Earth doth shine no less than the Moon; and the only remembering you of some things, which you knew of your self, and learn'd not of me, hath assured you thereof: for I taught you not that the Moon shews lighter by night than by day, but you understood it of your self; as also you could tell me that a little Cloud appeareth as lucid as the Moon: you knew also, that the illumination of the Earth cannot be seen by night; and in a word, you knew all this, without knowing that you knew it.[24]

This is not Platonism, but a parody of it. All the things already known by Simplicio are matters of comically simple experience--that the Moon appears brighter at night than during the day, that a little cloud appears as lucid as the Moon in the day sky, and that the Earth (the part we see of it) is not illuminated at night--not matters of rational principle as in Plato's <u>Meno</u>. What Galileo is showing us is that these experiences are not, by themselves, sufficient to give us this knowledge, but what is required is not more experience but a way of "looking" at the experiences we have already had. Galileo is laughing at the idea that Simplicio already knew that the Earth shines more brightly than the Moon, but he is quite serious in believing that he could have known it earlier if he had interpreted his experience correctly. This then is an answer to Simplicio's earlier statements that Salviati is arguing contrary to manifest experience. Experience is not a simple notion. It involves not only sensation but interpretive judgment, and these judgments are ordinarily "transparent" and made without our awareness. We must be aware and make only correct interpretations.

But how in general is one to go about interpreting experience? Galileo's rather broad answer is the method of Aristotle, <u>not</u> that of the Aristotelians of the day, that he favors, and it is to be remembered in the following that Simplicio is a representative of the sixteenth century Aristotelians, and not of Aristotle. This is a point made over and over again by Galileo; he plaintively asserts that had Aristotle looked through a telescope he would have become a Copernican.[25]

> SIMP. _Aristotle_ deduceth his principal Argument _a priori_, shewing the necessity of the inalterability of _Heaven_ by natural, manifest and clear principles; and then establisheth the same _a posteriori_, by sense, and the traditions of the antients.
> SALV. This you speak of is the Method he hath observed in delivering his Doctrine, but I do not bethink it yet to be that wherewith he invented it; for I do believe for certain, that he first procured by help of the senses, such experiments and observations as he could, to assure him as much as it was possible, of the conclusion, and that he afterwards sought out the means how to demonstrate it: For this is the usual course in demonstrative Sciences, and the reason thereof is, because when the conclusion is true, by help of resolutive Method, one may hit upon some proposition before demonstrated, or come to some principle known _per se_; but if the conclusion be false, a man may proceed _in infinitum_, and never meet with any truth already _known; but very_ oft he shall meet with some impossibility or manifest absurdity. Nor need you question but that _Pythagoras_ along time before he found the demonstration _for which_ he offered the Hecatomb, had been certain, that the square of the side subtending the right angle in a rectangle triangle, was equal to the square of the other two sides: and the certainty of the conclusion conduced not a little to the investigating of the demonstration . . .[26]

The last sentence in Salviati's statement bears some consideration. It would seem that Galileo has merged the physical and the mathematical in a way that is not typical of Aristotle. It is also strange in that it apparently indicates that Pythagoras was a follower of Aristotle's methods, which is either a simple mistake or a profound insight. We shall assume that it was the latter. The method here described as that of Aristotle is the method of _resolutio_ and _compositio_--a method which moves from sensory experience of particulars to general principles and then explains those particulars by deducing them from the principles.[27] There existed in mathematics a structurally similar method known as the method of analysis and synthesis[28] but it is quite clear that Aristotle, at least, saw these methods as distinct.[29] What we will try to show in the next few pages is that Galileo conceived of himself as having combined the two methods and having thereby created a notion of a mathematical physics. It was this combined method that also came to characterize Newton's work and so must have been of special interest to him.

The Dialogue makes it quite clear that it is a mathematical method that allows us to go beyond Aristotle in both the interpretation of our experience and in the ability to acquire demonstrative knowledge. Aristotle's claim in the Metaphysics[30] that one should not always expect necessity of the mathematical sort in dealing with the natural finds pronouncement in Simplicio and ironic echo in Sagredo,[31] but is refuted by the Dialogue as a whole.

Galileo's belief in the central role of mathematics in the correct interpretation of experience is also made evident through the irony of Sagredo when, in criticizing Chiaramonti,[32] he says,

> So that if from those observations, and from all the computations made thereon, the height of the Star be alwayes collected to be lesse than that of the Moon,

> it serves the Authors turn to convince all those Astronomers of most impardonable ignorance, that through the defect either of Geometry or Arithmetick, have not known how to draw true conclusions from their own observations themselves.[33]

That mathematics is not only the method of correct interpretation, which is to say discovery, of nature but also the means by which we can prove the truth of what we discover, is indicated by a qualification of the praise of Gilbert and his work on the magnet.

> SALV. That which I could have desired in Gilbert, is, that he had been a little greater Mathematician, and particularly well grounded in Geometry, the practice whereof would have rendered him less resolute in accepting those reasons for true Demonstrations, which he produceth for true causes of the true conclusions observed by himself. Which reasons (freely speaking) do not knit and bind so fast, as those undoubtedly ought to do, in that of natural, necessary, and lasting conclusions may be alledged.[34]

The application of Aristotle's method of resolution on our physical sensations resulted in generalized physical facts (natural laws or principles). This was never the same as the products of the method of analysis which was always a mathematical statement. Such a statement could never serve as an explanation of our physical sensations inasmuch as, according to Aristotle, they lacked any force regarding efficient and material causes. Mathematics was not of the physical or material but of the abstract. To use Aristotle's favorite example, the results of resolution are to those of analysis as "snub" is to "curved."[35] What Galileo does in the Dialogue is to attack this difference at its root.

On pages 184-7 of Dialogue II of the Dialogue Salviati and Simplicio discuss the applicability of mathematics to the material world. Salviati has just completed a demonstration of the fact that a sphere touches a plane in a single point and Simplicio responds by saying, "This demonstration holdeth in the abstracted, but not in the material spheres."[36] Salviati asks that an argument be given why what holds " . . . in the immaterial and abstracted" sphere should not hold in the material sphere.[37] Simplicio identifies the immaterial and abstract sphere with the perfect, and the material with the imperfect, saying, " . . . for it is not to be doubted, but that the imperfection of the matter, maketh the matters taken in concrete, to disagree with those taken in abstract."[38] It is thus being maintained by Simplicio that the immaterial, abstract and perfect are logically identical. Salviati, however, argues that the perfect is logically independent from the abstract and immaterial. It may be the case that there are no perfect spheres, but it is not a necessary truth that there are none. What keeps a material object from being a perfect sphere is not its material nature but certain "accidents" whose effects might (depending on the particular case) be discounted.

> SALV. Then when ever in concrete you do apply a material Sphere to a material plane, you apply an imperfect Sphere to an imperfect plane, & these you

say do not touch only in one point. But I must tell you, that even in abstract an immaterial Sphere, that is, not a perfect Sphere, may touch an immaterial plane, that is, not a perfect plane, not in one point, but with part of its superfices, so that hitherto that which falleth out in concrete, doth in like manner hold true in abstract. And it would be a new thing that the computations and rates made in abstract numbers, should not afterwards answer to the Coines of Gold and Silver, and to the merchandizes in conrete. But do you know Simplicius, how this commeth to passe? Like as to make that the computations agree with the Sugars, the Silks, the Wools, it is necessary that the accomptant reckon his tares of chests, bags, and such other things: So when the Geometricall Philosopher would observe in concrete the effects demonstrated in abstract, he must defalke the impediments of the matter, and if he know how to do that, I do assure you, the things shall jump no lesse exactly, than Arithmetical computations. The errours therefore lyeth neither in abstract, nor in conrete, nor in Geometry, nor in Physicks, but in the Calculator, that knoweth not how to adjust his accompts. Therefore if you had a perfect Sphere and plane, though they were material, you need not doubt but that they would touch onely in one point. And if such a Sphere was and is impossible to be procured, it was much besides the purpose to say, Quod Sphaera aenea non tangit in puncto.[39]

Galileo's point here is that when we consider the net weight of the sugar in a bag we are not dealing with abstract or immaterial sugar--not even an abstract or immaterial bag of sugar. The analogy we are supposed to draw is that when we are considering a frictionless inclined plane we are not considering an abstract or immaterial inclined plane. Thus mathematics, though of the perfect, is applicable to the material world, suitably considered, and not only the abstract and the immaterial.[40] After having shown in this way that the perfect-imperfect distinction cuts across the material-immaterial distinction, Galileo has Sagredo and Simplicio push the point (a bit too far) by claiming that any material object has the shape that it has, perfectly.[41]

Newton also seems to have been feeling his way into the problem of the applicability of mathematics to the material world. Using and elaborating on certain arguments he had found in More's The Immortality of the Soul, Newton asks us to " . . . suppose there were ciphers of such a nature & quality y^t they will resist being y^e same."[42] After showing that such "attomes" would be extended and indivisible, Newton says,

> I would not be mistaken as if I thought a point or cipher (which are nothings) were capable of powers or qualities but bekause I thought it a supposition easie to conceive of & fit for y^e purpose I ventured upon it & though it be impossible y^t y^e thing should be so yet it is not so to conceive it: nay if attomes be so small tis necessary to conceive they are terminated & touch others by Math: points & superficies at so small a distance as is described here, though held asund^e by y^e attome & no power of their owne.[43]

To return to Galileo, the mathematical method is then, a way of obtaining certain knowledge of the material world. Galileo must temper his optimism, however, in deference to the Church, and this he does not by denying the certainty of our knowledge but by restricting its range. His optimism concerning human understanding is put over against the view that man knows practically nothing (which he identifies with Socrates and the oracle). Galileo marks a difference between intensive understanding and extensive understanding. The few things that man can know he can know perfectly, but compared to the number of things that are to be known he knows little. Referring to mathematics, he has Salviati say, " . . . in which [Geometry and Arithmetic] Divine Wisdom knows infinite more propositions, because it knows them all; but I believe that the knowledge of those few comprehended by humane understanding, equalleth the divine, as to the certainty objective, for that it arriveth to comprehend the necessity thereof, than which there can be no greater certainty."[44] Which he clarifies somewhat by saying,

> . . . the better to express my self I say, that as to the truth, of which Mathematical demonstrations give us the knowledge, it is the same, which the divine wisdom knoweth; but this I must grant you, that the manner whereby God knoweth the infinite propositions, of which we understand some few, is highly more excellent than ours, which proceedeth by ratiocination, and passeth from conclusion to conclusion, whereas his is done at one single thought or intuition.[45]

He goes on to conclude,

> . . . that our understanding, both as to the manner and the multitude of the things comprehended by us, is infinitely surpast by the Divine Wisdom; but yet I do not so vilifie it, as to repute it absolutely nothing; yea rather, when I consider how many and how great misteries men have understood, discovered, and contrived, I very plainly know and understand the mind of man to be one of the works, yea one of the most excellent works of God.[46]

Although the elements of scepticism expressed above could be attributed soley to Galileo's fear of sharing the fate of Giordano Bruno, it should be noted that we have already argued, in Chapter I, that Galileo did see limits to our knowledge of the material world, especially as regards causes. This element of scepticism became in Galileo's hands a weapon to be used against the occult qualities of the Aristotelians.

> SALV. You are out, Simplicius, you should say, that every one knowes, that it is call Gravity: but I do not question you about the name, but the essence of the thing, of which essence you know not a tittle more than you know the essence of the mover of the stars in gyration; unlesse it be the name that hath been put to this, and made familiar, and domestical, by the many experiences which we see thereof every hour in the day,: but not as if we really understand any more, what principle or vertue that is which moveth a stone downwards, than we know who moveth it upwards, when it is separated from the projicient, or who moveth the Moon round, except (as I have said) onely the name, which more particularly and properly we have assigned to the motion of descent, namely, Gravity; whereas for the cause of circular motion, in more general termes, we assign the Vertue impressed, and call the same an Intelligence, either assisting, or informing; and to infinite other motions we ascribe Nature for their cause.[47]

Or, similarly, against the Aristotelian argument that the Copernican theory demands an incomprehensibly vast space, he queries,

> In a word, I ask of thee, O foolish man! Doth thy imagination comprehend that vast magnitude of the Universe, which than afterwards judgest to be too immense? If thou comprehendest it; wilt thou hold that thy apprehension extendeth it self farther than the Divine Power? wilt thou say, that thou canst imagine greater things than those which God can bring to passe? But if thou apprehendest it not, why wilt thou passe thy verdict upon things beyond thy comprehension?[48]

There is another strain of scepticism to be found in the Dialogue and that is the traditional suspicion of the senses. We have already seen how Galileo deals with the notion of manifest experience, and so we know that he believes that the errors of perception can be generally overcome by method.

> SALV. But I desire not to deduce precepts more profitable, or more certain, learning to more circumspect and less confident about that which at first blush is represented to us by the senses, which may easily deceive us.[49]

But he also believed that the senses themselves were sometimes ill equiped for scientific investigation. Salviati says in Dialogue III, "These things cannot be comprehended, save onely by the sense of seeing, the which by nature was not granted to man so perfect, as that it was able to attain to the discovery of such differences; nay even the very instrument of sight is an impediment to it self . . ."[50] But here, too, there is a remedy to the problem, viz., instrumentalities.

> But since that it hath pleased God in our age to vouchsafe to humane ingenuity, so admirable an invention of perfecting our sight, by multiplying it four, six, ten, twenty, thirty, and fourty times, infinite objects, that either by reason of their distance, or for their extream smallnesse were invisible unto us, have by help of the Telescope been rendered visible.[51]

This is a triumph over the errors of the senses, but a triumph of reason upon the senses--not a replacement of them. But such a use of reason is not a simple matter; method and genius are required.

> SAGR. Oh, Nicholas Copernicus, how great would have been thy joy to have seen this part of thy Systeme, confirmed with so manifest experiments [the relative sizes of planets at conjunction and opposition, and phases of Venus having been observed by means of the telescope]!
> SALV. 'Tis true. But how much lesse the fame of his sublime wit amongst the intelligent? when as it is seen, as I also said before, that he did constantly continue

> to affirm (being persuaded thereto by reason) that which sensible experiments seemed to contradict . . .[52]

And,

> These are those difficulties that make me wonder how Aristarchus and Copernicus, who must needs have observed them, not having been able for all that to salve them, have yet notwithstanding by other admirable occurences been induced to confide so much in that which reason dictated to them, as that they have confidently affirmed that the structure of the Universe could have no other figure than that which they designed to themselves.[53]

When we consider what influence all of the above might have had on Newton's thought we cannot help but be surprised that the only direct reference to Galileo in the "Quaestiones" is that 100 pounds will fall 100 braces in 5 seconds. We have already established Newton's interest in the relationship between experience and knowledge and we have just seen that Galileo had provided a rather detailed and original discussion of just this issue in the Dialogue. But on this issue their concerns were somewhat different. Newton and Galileo were both concerned with the relationship of our sense experience to knowledge of the physical world, but Newton seems to have been concerned first to establish the relation of sense experience to the soul, believing that only in understanding that relation would real knowledge of the physical world be possible. We have also seen, however, that Newton provided himself with a way around this problem by reason of his adoption of the primary-secondary quality distinction, although we have not yet considered whether he recognized it as such.

What must have been important to Newton's later thought was Galileo's arguments for the applicability of mathematics to scientific inquiry. It will be argued later that Newton's use of point masses, and mathematical and non-mathematical space and time were, at least in part, outgrowths of this Galilean account of mathematical physics.

Beyond the gathering of the physical facts that were always of great interest to him, Newton must have been intrigued by Galileo's handling of scepticism. The seventeenth century was an age of polemicism, and in addition to the specific individuals attacked there was that universal quarry: the sceptics and optimists (or dogmatists). Anyone who was guilty of either the one or the other of these two sins was denigrated by those who happily clung to both of them. The period was one of optimism regarding the scientific enterprise, but one could not speak or write of that optimism without paying tribute to scepticism as if knocking on wood. Yes, science had done marvelous things and would do many more, but the great mysteries would remain unsolved. It would not do to be too optimistic. This attitude, as we shall see, became codified in methodological principles that warned the practitioners of science not to go too far. This mixture of scepticism and optimism has a tradition going back to Erasmus, Montaigne, Charron[54] and others, but reaches a peak in Joseph Glanvill's <u>The Vanity of Dogmatizing</u>, a book which is almost a caricature of the seventeenth century's form of this "doctrine."

We have seen that Galileo shared in this tradition, which for him became a tool or method of finding demonstrations or convincing arguments and which delineated the boundaries of science. We will argue that it was this and more for Newton. The early years of 1661 to 1665, when he was an undergraduate and feeling his way into the new science, were filled with the contrary claims of the wonders and pretensions of science. Newton had to make peace with these claims before he could commit himself to science. Making peace however, was not an easy task for someone as intellectually demanding and concerned with man's place in nature as Newton. It is hard to imagine that Newton was not struck by Galileo's way of making peace by turning his scepticism to methodological caution and using it to catch out his enemies.

NOTES

CHAPTER IV

[1]Salusbury's *Mathematical Collections and Translations in Two Tomes* was published in two volumes, the first in 1661 and the second in 1665. Each volume had two parts. The second volume is very rare, most copies having been destroyed in warehouse during the fire of London. Santillana says that the only copy of the second volume is in the British Museum, but the Bodleian Library has a copy containing volume I, parts 1 and 2, and volume II, part 1. Part 2 of volume II is missing. Volume I, part 1 contains the *Dialogue*. Volume II, part 1 contains the *Discourse Concerning Two New Sciences* and volume II, part 2 contains a biography of Galileo.

[2]Galileo, *Systeme of the World: in Four Dialogues* in *Mathematical Collectiones and Translations in Two Tomes*, ed. Thomas Salusbury (London, 1661), vol. I part 1, p. 200. This work will be referred to as "*Dialogue*."

[3]*Ibid*.

[4]Galilei, *Systema cosmicum*, trans. M. Bernegger (London, 1663), 2nd Day, p. 311.

[5]Father Marin Mersenne attempted to verify the statement that 100 lbs. fell 100 braccia in 5 seconds by

experiment, and finding a large discrepancy between his results and Galileo's, concluded that either his equivalences of French and Italian measurements were wrong, or else that Galileo hadn't performed the experiment. Mersenne mentions this matter in his Harmonie Universelle, vol. I, p. 138 published in Paris in 1636. There is no reason to think that Newton read this book during the 1661-1665 period. Galileo is, of course, wrong by almost a factor of two.

[6]Salusbury writes that 100 yards equals 150 2/5 braccia. 1 braccia = $100/150.4 \cong 2/3$ yards = 2 feet.

[7]John Herivel, The Background to Newton's Principia, (Oxford: Oxford University Press, 1965), p. 189.

[8]Newton manuscript, University Library, Cambridge, England (Add. 3958, folio 45). Called the Vellum Manuscript because it is a torn part of a lease with Newton's MS being on the back and dating from 1665-1666. See discussion of this MS in Herivel, The Background to Newton's Principia.

[9]It is doubtful that Newton could read Italian at this early period of his life and so the possibility of his having read the Italian editions has been discounted. Newton's library did contain a French-Italian dictionary, Dictionaire Francais & Italien by Jean Antoine Fenice (Paris, 1585) (Shelf mark NQ.10.138 Trinity College Library, Cambridge), but given his remark, " . . . which (not being

so ready in ye French tongue my selfe as to reade it without the continuall use of a Dictionary) I committed to ye perusal of another . . ." made in a letter to Collins dated 20, May 1673 (Item 110 in vol. I of the Newton Correspondence), one can't imagine him reading in Italian by the use of it in the 1661-1665 period. There does of course exist the possibility that this passage came to him from another source. Having assured myself that it is not quoted in any of the other books mentioned in the "Quaestiones," I have concluded that he read the Salusbury edition of the Dialogue.

[10]Dialogue, Dialogue I, p. 21.

[11]Ibid., Dialogue I, p. 22.

[12]The term "manifest experience" occuring in the Salusbury translation of the Dialogue is a literal translation of Galileo's own phrase which was "esperienze manifeste." See Galileo Galilei, Massimi Sistemi del Mondo Tolemaico, E Copernicano (Florence, 1632), p. 25.

[13]Dialogue, Dialogue II, p. 197.

[14]Santillana reformulates the argument in essentially the same way in a footnote to page 154 in Galileo, Dialogue on the Great World Systems, Introduction and revisions by Giorgio de Santillana (Chicago: University of Chicago Press, 1953).

[15]Dialogue, Dialogue II, p. 143.

[16]Ibid., Dialogue II, p. 151. [17] Ibid.

[18]See, for example, Alexandre Koyré, Metaphysics and

Measurement (London: Chapman & Hall, 1968), pp. 42-3.

Salviati, on pages 169-70 of the Dialogue, says,

> What I think of the opinion of Plato, you may gather from my words and actions. I have already in the precedent conferences expresly declared my self more than once; I will pursue the same style in the present case, which may hereafter serve you for an example, thereby the more easily to gather what my opinion is touching the attainment of knowledge, when a time shall offer upon some other day: but I would not have Sagredus offended at this digression.

Santillana interprets this as a denial of Platonism while Koyré interprets it as an admission of Platonism.

[19]Dialogue, Dialogue I, p. 72. [20]Ibid. [21]Ibid.

[22]Ibid.

[23]Ibid., Dialogue I, p. 74(1). There is no page 73 and two page 74's. I have called the first 74(1) and the second 74(2).

[24]Ibid., Dialogue I, p. 74(2).

[25]Salviati rhetorically asks Simplicio in Dialogue II,

> Do you question whether Aristotle, had he but seen the novelties discovered in Heaven, would not have changed his opinion, amended his Books, and embraced the more sensible Doctrine; rejecting those silly Gulls, which too scrupulously go about to defend what ever he hath said . . .

From Dialogue, pp.93-4.

[26]Ibid., Dialogue I, pp. 37-8.

[27]The method of resolution and composition has its origin in Aristotle's Posterior Analytics, Book I, section 1, where Aristotle writes,

> All instruction given or received by way of argument proceeds from pre-existent knowledge. This becomes evident upon a survey of all the species of such instruction. The mathematical sciences and all other speculative disciplines are acquired in this way, and so are the two forms of dialectical reasoning, syllogistic and inductive; for each of these latter makes use of old knowledge to impart knew, the syllogism assuming an audience that accepts its premisses, induction exhibiting the universal as implicit in the clearly known particular.

The above is taken from Analytica Posteriora, trans. G. R. G. Mure, in The Works of Aristotle Translated into English, ed. W. D. Ross, (London, Oxford University Press, 1928), vol. I, 71^{a}1-7.

It is interesting to compare this with Bacon's formulation and comparison of the Aristotelian method with his own:

> There are and can be only two ways of searching into and discovering truth. The one flies from the senses and particulars to the most general axioms, and from these principles, the truth of which it takes for settled and immovable, proceeds to judgment and to the discovery of middle axioms. And this way is now in fashion. The other derives axioms from the senses and particulars, rising by a gradual and unbroken ascent, so that it arrives at the most general axioms last of all. This is the true way, but as yet untried.

This is taken from Francis Bacon, The New Organon, ed. Fulton H. Anderson, (New York: Bobbs-Merrill, 1960), p. 43.

The Italian Aristotelians claimed that they derived the terms "resolutio" and "compositio" from Galen, Cicero and Boethius. But the Arabic commentator on Galen, Hali ('Ali ibn Ridwan) writing about 1060 describes its source as Aristotle's Posterior Analytics. For an excellent discussion of the history of this method see John Herman Randall, Jr.. *The School of Padua and the Emergence of Modern Science*, (Padua, 1961), pp. 27-67; also A. C. Crombie, *Robert Grosseteste and the Origin of Experimental Science 1100-1700*, (Oxford: Clarendon Press, 1953).

[28]The method of analysis and synthesis is attributed by Proclus (410-485 A.D.) in his *Commentary on Euclid* to Plato. T. L. Heath in *The Thirteen Books of Euclid's Elements*, (New York: Dover Publications, 1956), vol. I, pp. 137-8, indicates that a definition of analysis and synthesis is to be found interpolated into the MSS of the *Elements*. This definition, as given by Heath on page 138 of the *Elements*, is as follows:

> Analysis is an assumption of that which is sought as if it were admitted <and the passage> through its consequences to something admitted (to be) true.
> Synthesis is an assumption of that which is admitted <and the passage> through its consequences to the finishing or attainment of what is sought.

The classical statement of the method is by Pappus (latter part of third century A.D.) in his *Collections*, Book VII, "On the 'Treasury of Analysis'" which T. L. Heath quotes in his *A History of Greek Mathematics*, (Oxford: Clarendon Press, 1921), vol II, pp. 400-1, as follows:

> *Analysis*, then takes that which is sought as if it were admitted and passes from it through its successive consequences to something which is admitted as the result of synthesis: for in analysis we assume that which is sought as if it were already done . . . and we inquire what it is from which this results, and again what is the antecedent cause of

the latter, and so on, until by so retracing our steps we come upon something already known or belonging to the class of first principles, and such a method we call analysis as being solution backwards . . . .

But in synthesis, reversing the process, we take as already done that which was last arrived at in the analysis and, by arranging in their natural order as consequences what before were antecedents, and successively connecting them one with another, we arrive finally at the construction of what was sought; and this we call synthesis.

Now analysis is of two kinds, the one directed to searching for truth and called theoretical, the other directed to finding what we are told to find and called problematical. (1) In the theoretical kind we assume what is sought as if it were existent and true, after which we pass through its successive consequences, as if they too were true and established by virtue of our hypothesis, to something admitted: then (a), if that something admitted is true, that which is sought will also be true and the proof will correspond in the reverse order to the analysis, but (b), if we come upon something admittedly false, that which is sought will also be false. (2) In the problematical kind we assume that which is propounded as if it were known, after which we pass through its successive consequences, taking them as true, up to something admitted: if then (a) what is admitted is possible and obtainable, that is, what mathematicians call given, what was originally proposed will also be possible, and the proof will again correspond in the reverse order to the analysis, but if (b) we come upon something admittedly impossible, the problem will also be impossible.

Heath writes in his Mathematics in Aristotle, (Oxford: Clarendon Press, 1949), p. 272, that,

The method is said by Proclus to have been invented by Plato and handed over to Leodamas. But it looks as though the statement were due to some confusion, some supposed connexion with Plato's method of division, which has, no doubt, some points in common with it. The method itself must have been in use before Plato: the Pythagoreans must certainly have used it.

He argues on page 168 of his A History of Greek Mathematics, as follows:

They [the Pythagoreans] had discovered, or were aware of the existence of, the five regular solids. These they may have constructed empirically by putting together squares, equilateral triangles, and pentagons. This implies that they could construct a regular pentagon and, as this construction depends upon the construction of an isosceles triangle in which each of the base angles is double of the vertical angle, and this again on the cutting of a line in extreme and mean ratio, we may fairly assume that this was the way in which the construction of the regular pentagon was actually evolved. It would follow that the solution of problems by analysis was already practised by the Pythagoreans, notwithstanding that the discovery of the analytical method is attributed by Proclus to Plato.

[29]See note 35 below.

[30]Aristotle writes in the Metaphysics, Book a.2, 995^a15,

> The minute accuracy of mathematics is not to be demanded in all cases, but only in the case of things that have no matter. Hence its method is not that of natural science; for presumably the whole of nature has matter.

The above is taken from, Metaphysica trans. W. D. Ross in The Works of Aristotle Translated into English, ed. W. D. Ross, (Oxford: Clarendon Press, 1928), vol. VIII.

[31]Simplicio, in Dialogue, Dialogue I, p. 6, says,

> I will not say that this your argument may not be concludent; yet this I say with Aristotle, that in things natural it is not alwaies necessary, to bring Mathematical demonstrations.

And Sagredo, in Dialogue III, p. 373, says,

> I am . . . little lesse satisfied with this reason, that if it were a pure Geometrical Demonstration; and because we speak of a Physical Problem, I believe that also Simplicius will find himself satisfied as far as natural science admits, in which he knows that Geometrical evidence is not to be required.

[32]Scipione Chiaramonti of Cesena, a professor in

Perugia, was the author of a book maintaining that the novae of 1572, 1600 and 1604 were consistent with Aristotelian doctrines. The book, De Tribus novis stellis quae Annis 1572, 1600, 1604, comparuere libri tres Scipionis Claramonti Caesenatis. In quibus demonstratur rationibus ex parallaxi praesertim ductis Stellas eas fuisse sublunares et non coelestes, adversum Tychonem, Gemmam, Maestlinum, Digesseum, Hagecium, Santucium, Keplerum aliosque plures quorum rationes in contrarium adductae solvuntur (Caesenae, 1628), is introduced into the Dialogue by Simplicio.

[33]Dialogue, Dialogue III, p. 254.

[34]Ibid., Dialogue III, pp. 369-70.

[35]Aristotle, in the Physics, Book II.2, 193^b30, writes,

> Now the mathematician, though he too treats of these things [surfaces, etc.] , nevertheless does not treat of them as the limits of a physical body; nor does he consider the attributes indicated as the attributes of such bodies. That is why he separates them; for in thought they are separable from motion, and it makes no difference, nor does any falsity result, if they are separated. The holders of the theory of Forms do the same, though they are not aware of it; for they separate the objects of physics, which are less separable than those of mathematics. This becomes plain if one tries to state in each of the two cases the definitions of the things and of their attributes. 'Odd' and 'even', 'straight' and 'curved', and likewise 'number', 'line', and 'figure', do not involve motion; not so 'flesh' and 'bone' and 'man' - these are defined like 'snub nose', not like 'curved'.

The above is taken from Aristotle, Physica, trans. R. P.

Hardies, in The Works of Aristotle Translated into English, ed. W. D. Ross (Oxford: Clarendon Press, 1930), vol. II.

[36]Dialogue, Dialogue II, p. 184. [37]Ibid.

[38]Ibid. See also note 30 above.

[39]Ibid., Dialogue II, p. 185.

[40]Problems of great interest are hidden behind the term "defalke." It is clear that in order to find the net weight of a bag of sugar one must subtract the weight of the bag, but this is because we know the sugar independently of knowing the bag, i.e., we can experience the bag as well as the sugar. It is not so clear that we can know the inclined plane independently of knowing its friction and *vice versa*. The question of what things are to be "defalkated" seems to be a function of knowing at the start what will be left when we finish. Although this makes very good sense in the case of the sugar it is not so obvious in the case of the inclined plane. It is possible that just this issue was the cause of Galileo's disregard of Kepler's ellipses. For Galileo the motions of the planets were circular, this being the perfect case resulting from the "defalkation" of various "accidental" properties. Perhaps his view of Kepler's theory of ellipses was that it had failed to discount the friction of an inclined plane. Galileo does not however, accuse Kepler of this error. He has Salviati condemn him for a belief in occult properties and the moon as the cause of the tides.

> But amongst all the famous men that have philosophated upon this admirable effect of Nature [the tides], I more wonder at Kepler than any of the rest, who being of a free and piercing wit, and having the motion ascribed to the Earth, before him, hath for all that given his ear and assent to the Moons predominancy over the Water, and to occult properties, and such like trifles.

The above is taken from, Dialogue, Dialogue IV, p. 422.

[41]Dialogue, Dialogue II, p. 187.

[42]"Quaestiones," folio 119r. Both this folio and the following are crossed out by Newton.

[43]Ibid., folio 119v.

[44]Dialogue, Dialogue I, p. 86.

[45]Ibid., Dialogue I, p. 87. [46]Ibid.

[47]Ibid., Dialogue II, p. 210.

[48]Ibid., Dialogue III, pp. 332-3. In addition we have Sagredo's statement in Dialogue III, p. 334:

> Moreover, who will presume to say that the space which they call too vast and uselesse between Saturn and the fixed stars, is void of other mundane bodies? Must it be so, because we do not see them? Then the four Medicean Planets, and the companions of Saturn came first into Heaven, when we began to see them, and not before? And by this rule the innumerable other fixed stars had no existence before that men did look on them? and the cloudy constellations called Nebulosie were at first only white flakes, but afterwards with the Telescope we made them to become constellations of many lucid and bright stars. Oh presumptuous, rather oh rash ignorance of man!

[49]Ibid., Dialogue II, p. 230.

[50]Ibid., Dialogue III, p. 303. [51]Ibid.

[52]Ibid., Dialogue III, p. 306.

[53]Ibid., Dialogue III, pp. 302-3.

[54]See S. Medcalf's Introduction to John Glanvill, The Vanity of Dogmatizing: The Three Versions, ed. S. Medcalf, (Hove, Sussex: The Harvester Press, 1970).

CHAPTER V

NEWTON AND WILKINS AND BATE

Before we go on to consider Glanvill's possible influence on Newton and Newton's early theory of matter, we should consider two books which may have had an earlier influence on Newton than that of all the others so far discussed.

During the period from 1659 to about 1661 Newton used a notebook now in the Morgan Library of New York. This notebook is inscribed, "Isacus Newton hunc librum possidet. teste Edvardo Secker. pret: 2^{d} ob. 1659," which inscription was probably written by the witness Edward Secker. The date of 1661 seems a correct terminal date given the fact that the notebook contains an ecclesiastical calendar in Newton's hand dated 1662-1689. It would seem reasonable that such a calendar would not be drafted after 1662 nor very long before it and so the date 1661 would appear the likely date of the writing of the calendar.

Of interest for this inquiry is the fact that this notebook contains many paraphrases and excerpts from

John Bate's The Mysteryes of Nature, and Art, (London, 1634)[1] and John Wilkins' Mathematicall Magick or, The Wonders that may be Performed by Mechanicall Geometry, (London, 1648).

John Bate's book appears to have been of great interest to the seventeen year old Newton. It contains instructions for the construction of all sorts of devices--clocks, fountains, fireworks, mechanical vehicles, and even for drawing--many of which Newton apparently constructed.[2] The theoretical content of The Mysteryes of Nature, and Art was very small. The only statement of general principles is at the beginning of the section on fireworks and they are rather strictly Aristotelian. Furthermore, they are in fact not used in the exposition of any of the devices.[3]

John Wilkins' Mathematicall Magick is a rather more respectable book containing an introduction, of fairly high quality, to the simple machines: the balance, the lever, the wheel, the pulley, the wedge and the screw. Although there are mechanical devices described in Wilkins' book they are almost all theoretical devices being used to show the application of general principles.

Wilkins' text as well as his title emphasizes the importance of mathematics as a part of the sciences. The importance of mathematics for the sciences was not evident from the writings of the ancients, according to Wilkins, for, he claims, they wrote only the mathematics of their mechanical discoveries in order to hide those discoveries from the vulgar. The point is derived from Francis Bacon who saw the ancients as intentionally obfuscating reports of their discoveries, and he claimed that it was for this reason that alchemy and magic were not sciences. Science was for him characterized by its collective and progressive (cumulative) nature as against the privacy of alchemy and magic. What Wilkins appears to be claiming is that the marvelous discoveries and inventiones of the ancients were a product of their mechanical geometry, but that the ancient authors seeking to protect their discoveries wrote only of the mathematics of them, abstracted from its application to mechanical discovery and invention, thus obscuring its true nature as part of science. Realizing that many of his readers would not understand how mechanics could be classified as a mathematical subject, he explained,

> The art it self may be thus described, to be a Mathematical discipline, which by the help of Geometricall principles doth teach to contrive severall weights and powers, unto any kind, either of motion or rest, according as the Artificer shall determine.
>
> If it be doubted how this may be esteemed a species of Mathematicks, when as it treats of weights, and not of quantity; For satisfaction to this, there are two particulars considerable.
>
> 1. Mathematicks in its latitude is usually divided into pure and mixed. And though the pure do handle only abstract quantity in the generall, as Geometry, Arithmetick: yet that which is mixed doth consider the quantity of some particular determinate subject. So Astronomy handles the quantity of heavenly motions, Musick of sounds, and Mechanicks of weights & powers.
>
> 2. Heavinesse or weight is not here considered, as being such a naturall quality, whereby condensed bodies

> do themselves tend downwards; but rather as being an affection, whereby they may be measured. And in this Aristotle himselfe referres it amongst the other species of quantity, as having the same proper essence, which is to be compounded of integrall parts. So a pound doth consist of ounces, drams, scruples. Whence it is evident, that there is not any such repugnancy in the subject of this art, as may hinder it from being a true species of Mathematicks.[4]

Of particular interest here is the claim that weight is not, in the context of mechanical geometry, a quality but a quantity or affection whereby the tendency downward of various objects can be measured; that what characterises this dispositional quality as measurable is its "proper essence, which is to be compounded of integrall parts." This points to a distinction between measurable and non-measurable properties.[5] Further, since the correct method of science is mathematical and the mathematical is of that which can be measured, science is concerned with measurable rather than non-measurable properties. It would be interesting to know what other qualities Wilkins classified as measurable and how he would have classified powers. Would this distinction of measurable and non-measurable parse out qualities in the same way that the primary-secondary quality distinction did? More importantly, was the young Newton likely to have identified the two distinctions?

On pages 115-6 of Mathematicall Magick Wilkins informs us that measurable properties that cannot be seen may still be real.

I know it is the assertion of Cardan, Motus valde

> tardi, necessario quietes habent intermedias. Extreme slow motions have necessarily some intermediate stops and rests: But this is onely said, not proved, and he speaks it from sensible experiments, which in this case are fallible. Our senses being very incompetent judges of the severall proportions, whether greatnesse or littlenesse, slownesse or swiftnesse, which there may bee amongst things in nature. . . . 'Tis certain that our senses are extreamly disproportioned for comprehending the whole compasse and latitude of things. And because there may be such difference in the motion as well as in the magnitude of bodies; therefore, though such extream slownesse may seem altogether impossible to sense and common apprehension, yet this can be no sufficient argument against the reality of it.[6]

These passages may well have led the young Newton to think that measurable qualities were real qualities and that the qualities that we thought we perceived in objects might or might not be there.

Wilkins' attitude toward Aristotle is also of interest. He is not beyond criticizing Aristotle (or the author he takes to be Aristotle) but usually does so in a way that also implies praise. In discussing the manner of application of the wedge he indicates that a blow to the back of a wedge accomplishes more than placing a weight upon it. This, he says, is a great mystery.

> Aristotle [pseudo-Aristotle of the Mechanics], Cardan, and Scaliger, doe generally ascribe it unto the swiftnesse of that motion; But there seems to be something more in the matter then so; for otherwise it would follow that the quick stroak of a light hammer, should be of greater efficacy, then any softer and more gentle striking of a great sledge.[7]

Later, when he introduces the screw, Wilkins says, "Aristotle himself doth not so much as mention this instrument, which yet notwithstanding is of greater force and subtility, then any of the rest."[8]

If a hero emerges in Wilkins' book it is Archimedes--Archimedes who understood the mathematical principles that lay behind the simple machines and practiced the art of geometrical mechanics. Galileo too makes Archimedes his hero, setting him against Aristotle who knew how to praise mathematics (although thinking that Plato had been misled by too much of it) but not how to use it.

NOTES

CHAPTER V

[1]The title page contains the description, "Conteined in foure severall Tretises, the first of Water workes the second of Fyer workes, the third of Drawing, Colouring, Painting, and Engraving, the fourth of divers Experiments, as wel serviceable as delightful: partly collected, and partly of the Authors Peculiar Practice, and Invention." The book had three editions: 1634, 1635 and 1654. Frank E. Manuel refers to these various editions in his <u>A Portrait of Isaac Newton</u>, p. 406, n. 12, where he writes, "If Newton had access only to the 1634 or 1635 editions he saw illustrations of male and female heads, but no bodies; full naked male and female figures did not appear until the 1654 edition." Apparently the relevant pages were missing from the copies Prof. Manuel examined, but the nudes did appear in all three editions and are present in the Bodleian Library copies of the 1634 and 1635 editions (shelf marks 4^{o}g. 12 Med. and Douce B.B. 382 respectively).

[2]A letter written by Dr. William Stukeley based upon conversations with Newton in the last years of his

life and with people that had known the young Newton contains the following description of some of the young Newton's constructions:

> Sir Isaac's water clock is much talked of. This he made out of a box he begged of Mr. Clark's (his landlord) wife's brother. As described to me, it resembled pretty much our common clocks and clock-cases, but less; for it was not above four feet in height, and of a proportionable breadth. There was a dial plate at the top with figures of the hours. The index was turned by a piece of wood, which either fell or rose by water dropping. This stood in the room where he lay, and he took care every morning to supply it with its proper quantity of water; and the family upon occasion would go to see what was the hour by it. . . . all holidays, and what time the boys had allowed to play, he spent entirely in knocking and hammering in his lodging room, pursuing that strong bent of his inclination not only in things serious, but ludicrous too, and what would please his school fellows, as well as himself; yet it was in order to bring them off from trifling sports, and teach them, as we may call it, to play philosophically, and in which he might willingly bear a part, and he was particularly ingenious at inventing diversions for them, above the vulgar kind. As for instance, in making paper kites, which he first introduced here. He took pains, they say, in finding out their proportions and figures, and whereabouts the string should be fastened to the greatest advantage, and in how many places. Likewise he first made lanterns of paper crimpled, which he used to go to school by, in winter mornings, with a candle and tied them to the tails of the kites in a dark night, which at first affrighted the country people exceedingly, thinking they were comets. It is thought that he first invented this method; I can't tell how true. They tell us how diligent he was in observing the motion of the sun, especially in the yard of the house where he lived, against the walls and roofs, wherein he would drive pegs, to mark the hours and half hours made by the shade, which by degrees from some years observations, he had made very exact, and any body knew what o'clock it was by Isaac's dial, as they ordinarily called it; thus in his youngest years did that immense genius discover his sublime imagination, that since has filled, or rather comprehended the world.

The above is taken from Edmund Turnor <u>Collections for the</u>

History of the Town and Soke of Grantham (London, 1806), pp. 177-8.

[3]The rules given are as follows:

> Certaine Praecognita or Principles, wherein are contayned the causes and reasons of that which is taught in this Booke.
> 1 The foure Elements, Fire, Ayre, Earth, and Water are the prima principia (I meane the materialls) whereof every sublunary body is composed, and into the which it is at last dissolved.
> 2 Every thing finding a dissolution of those naturae catenae, that is, meanes whereby their principia are are connected and joyned together, their lighter parts ascend upward, and these that are more grosse and heavy, doe the contrary.
> 3 It is impossible for one and the selfe same body to possesse at one time two places; It followeth therefore, that a dense body rarified, and made thin, eyther by actuall or potentiall fire, requireth a greater quantity of room to be conteyned in, than it did before. Hence it is, that if you lay your hand upon a glasse, having a straight mouth reverst into a dish of water, it rarifieth the ayre contayned therein, and makes it breake out thorow the water in bubbles. Also, that gun-powder inclosed in the barrell of a gun, being rarified by fire, applyed unto the touch-hole, it seeketh a greater quantity of roome, and therefore forceth the bullet out of the barrell. This is called violent motion.
> 4 According unto the strength and quantity of a dense body rarified, and according unto the forme and length of its enclosure, it forceth its compresser further or nearer at hand.

The above is taken from pp.93-4 of the 1635 edition, which passages differ only in spelling from the 1634 edition.

[4]John Wilkins, Mathematicall Magick or, The Wonders that may be Performed by Mechanicall Geometry (London, 1648), pp. 11-2.

[5]In the Categories Aristotle distinguishes between two kinds of quantity; the discrete and the continous. At

4^b22 he tells us that number and language are discrete and that line, surfaces, bodies and time and place are continuous. In the Metaphysics, Book I.1, Aristotle says that the measure is of the "one," of the integral, but this does not require that the thing measured be a discrete quantity in kind for it is enough that we be able to consider it in thought as consisting of parts--" . . . even in lines [continuous quantity] we treat as indivisible the line a foot long." This last is taken from The Works of Aristotle Translated into English, ed. W. D. Ross, Metaphysica, vol. VIII, Book I.1, 1052^b32.

[6]Wilkins, pp. 115-6. [7]Ibid., p.55.

[8]Ibid., p. 57.

CHAPTER VI

NEWTON AND GLANVILL

Reading Glanvill

We have mentioned Joseph Glanvill's The Vanity of Dogmatizing as a book which was almost a caricature of the seventeenth century ambivalence toward science and as the culmination of a sceptical but optimistic tradition.

Newton apparently included this book amongst his reading in the 1661-1665 period. Glanvill is explicitly mentioned twice in the "Quaestiones." The first mention is on folio 109r, headed, "Immagination & Phantasia & invention," where Newton writes,

> A man by heitning his fansie & immagination may bind anothers to thinke what hee thinks as in y^e story of y^e Oxford scollar in Glanvill Van of Dogmatizing.

The second is on folio 117r, headed, "Of Motion," where Newton writes,

> In a wheele (divided into 24 parts by y^e 24 letters. A cannot move before b nor b before c etc to Z, y^n z will not move untill A hath nor A till z y^e reason is becaus a can have no place but b's nor y^t till b hath left it. If they move all together y^n in y^e instant y^t b leaves its place it is in't or not if in't y^n a can't move onto't in y^e same instant y^t it leaves it if not in't y^n it had left it before. A less & greater ● in a wheele move equally swift [illegible] y^e ([illegible] or els a straight line drawne from y^e

> center to y^e circumference would be inflected i.e if some parts move faster y^n others) yet y^e greater circle passeth over more space.
> A little wheele on y^e same axis w^{th} 2 large ones will pass over equall space w^{th} equall revolutions. Glanvill

The reference on folio 109r is to pages 196-8 of The Vanity of Dogmatizing[1] where Glanvill tells the story of the gypsy scholar.

A student at Oxford University was forced by his financial condition to seek his fortune in the world. His difficulties there led to his joining a " . . . company of Vagabond Gypsies, whom occasionly he met with, and to follow their Trade for a maintenance."[2] He was soon taught their "Mystery" at which he grew very proficient. Having met two former friends he " . . . told them, that the people he went with were not such Impostours as they were taken for, but that they had a traditional kind of learning among them, and could do wonders by the power of Imagination, and that himself had learnt much of their Art . . ."[3] To convince them of the truth of this he left them to talk together and then returned to tell them what they had said in his absence. He then explained that,

> . . . what he did was by the power of Imagination, his Phancy binding theirs; and that himself had dictated to them the discourse, they had held together, while he was from them: That there were warrantable wayes of heightening the Imagination to that pitch, as to bind others . . .[4]

Newton's mention of Glanvill's gypsy scholar story is made the more interesting by its juxtaposition to Newton's description of his after image experiments. This description begins on folio 109r immediately below the reference to Glanvill but appears later in time judging by the excited open hand writing with which it begins. The importance of the juxtaposition lies in Newton's interpretation of his after image experiments. The fact that Newton was able to "conjur up" his after image by imagining the sun is diagnosed as the power of the imagination to have the same " . . . operation uppon y[e] spirits in my optick nerve & y[t] y[e] same motions are caused in my braines . . ." Thus both the Glanvill story and Newton's interpretation of his experiments make much of the power of imagination. That this "power of the imagination" is not really different from a notion of the power of the will, to bind others, say, should be clear from the story of the gypsy scholar. This power of the imagination or will was to figure very large, as we shall see, in the slightly later manuscript of "De gravitatione et aequipondio fluidorum."

The reference on folio 117r is to chapter VI, pages 54-61 of <u>Vanity</u> where Glanvill writes,

> . . . For let's suppose the wheel to be divided according to the <u>Alphabet</u>. Now in motion there is a change of place, and in the motion of a <u>wheel</u> there is a succession of one part to another in the same place; so that it seems unconceivable that A. should move until B. hath left its place; For A. cannot move, but it must acquire some place or other. It can acquire none but what was B's, which we suppose to be most immediate to it. The same space cannot contain them both. And therefore B. must leave its place, before A. can have it; Yea, and the nature of its succession requires it. But

> now B, cannot move, but into the place of C; and C. must be out, before B. can come in: so that the motion of C. will be pre-required likewise to the motion of A; & so onward till it comes to Z. Upon the same accounts Z. will not be able to move, till A. moves, being the part next to it: neither will A. be able to move (as hath been shown) till Z. hath. And so the motion of every part will be pre-required to it self. . . .
> . . . suppose a right line drawn from the centre to the circumference, and it cannot be apprehended, but that the line should be inflected, if some parts of it move faster then others . . . .
> And you'l find that the little wheel will move over the same space in equal times with equal circulations, with the great ones, and describe as long a line.[5]

Glanvill was an extremely entertaining writer but even more an unsettling one. The Vanity of Dogmatizing was a book that must have both pleased and upset the young Newton for what it gives with one hand it takes away with the other.

Glanvill tells us at one place that, "The last Ages have shewn us what Antiquity never saw; no, not in a Dream."[6] And at another, " . . . to say, the principles of Nature must needs be such as our Philosophy makes them, is to set bounds to Omnipotence, and to confine infinite power and wisdom to our shallow models."[7]

Glanvill's oscillations between expressions of the wondrousness of science and its inability to achieve certain knowledge seem in marked contrast to the complete confidence of Newton's mature work, of which it may be said, as it was of Bacon, that he wrote philosophy like a Lord Chancellor. But I think that this can be misleading. Newton, in his early years, showed every indication of sharing in the same tradition as Glanvill.

A Newtonian Theory of Matter

Newton gives us reason to believe that we can never achieve certainty as to the real nature of things by means of the sciences. The principal difficulty is that the nature of substance cannot be known by virtue of its qualities and these are all that we can directly know. In an early manuscript dating from about 1665-1669 and entitled "De gravitatione et aequipondio fluidorum" Newton writes,

> . . . it remains to give an explanation of the nature of body. Of this, however, the explanation must be more uncertain, for it does not exist necessarily but by divine will, because it is hardly given to us to know the limits of the divine power, that is to say whether matter could be created in one way only, or whether there are several ways by which different things similar to bodies could be produced. And although it scarcely seems credible that God could create beings similar to bodies which display all their actions and exhibit all their phenomena and yet are not in essential and metaphysical constitution bodies; as I have no clear and distinct perception of this matter I should not dare to affirm the contrary, and hence I am reluctant to say positively what the nature of bodies is, but I rather describe a certain kind of being similar in every way to bodies, and whose creation we cannot deny to be within the power of God, so that we can hardly say that it is not body.[8]

The following possibility is then put forward:

> If he [God] should exercise this power, and cause some space projecting above the Earth, like a mountain or any other body, to be impervious to bodies and thus stop or reflect light and all impinging things, it seems impossible that we should not consider this space to be truly body from the evidence of our senses (which constitute our sole judges in this matter); for it will be tangible on account of its impenetrability, and visible, opaque and coloured on account of the reflection of light, and it will resonate when struck because the adjacent air will be moved by the blow. . . . It would have shape, be tangible and mobile, and be capable of reflecting and being reflected, and no less constitute

> a part of the structure of things than any other corpuscle, and I do not see that it would not equally operate upon our minds and in turn be operated upon, because it is nothing more than the product of the divine mind realized in a definite quantity of space. For it is certain that God can stimulate our perception by his own will, and thence apply such power to the effects of his will.[9]

But as in Glanvill this scepticism is accompanied by a solution of a kind.[10] The proposed solution does not give us knowledge of matter, but it does give us a way around our ignorance and makes a methodology of it; this methodology is a form of phenomenalism.

In "De gravitatione et aequipondio fluidorum" Newton does more than sceptically speculate about the possibility of God's having created bodies in various ways, but takes the bull by the horns and writes,

> Thus the preconseption just mentioned [that bodies have a complete, absolute and independent reality in themselves] must be laid aside, and substantial reality is rather to be ascribed to these kinds of attributes which are real and intelligible things in themselves and do not need to be inherent in a subject, than to the subject which we cannot conceive as dependent without difficulty . . .[11]

"De gravitatione" is ostensibly a treatise on the gravity and equilibrium of fluids and solid bodies in fluids. It quickly becomes, however, a polemic against Descartes' notions of motion and body. Newton attempts to show that pure extension characterizes space and not body. Extension becomes, for him, a necessary condition for existence. Since this Hobbesian principle was adopted by him in its Morean form[12] he treats it as implying that God and spirit are extended. When he considers the nature of body and the power of God it becomes clear that bodies are,

> . . . determined quantities of extension which omnipresent God endows with certain conditions. These conditions are, (1) that they be mobile . . . (2) that two of this kind cannot coincide anywhere; that is, that they may be impenetrable, and hence that when their motions cause them to meet they stop and are reflected in accord with certain laws; (3) that they can excite various perceptions of the senses and the fancy in created minds, and conversely be moved by them, nor is it surprising since the description of the origin is founded in this.[13]

The concept of material substance as an underlying substratum that causes (can excite) "various perceptions of the senses" is dismissed and replaced by God's will. Matter, as a substance, is termed, "the vulgar notion . . . of body,"[14] "a certain unintelligible reality"[15] and "a path to Atheism."[16]

Within the context of such an approach it does not seem possible to consider primary qualities as representations of qualities (properties) really in the object, at least not in the sense that our sensations are caused by these qualities. Yet earlier in "De gravitatione" Newton wrote,

> . . . since body is here proposed for investigation not in so far as it is a physical substance endowed with sensible qualities but only in so far as it is extended, mobile and impenetrable, I have not defined it in a philosophical manner, but abstracting the sensible qualities (which Philosophers also should abstract, unless I am mistaken, and assign to the mind as various ways of thinking excited by the motions of bodies) I have postulated only the properties required for local motion. So that instead of physical bodies you may understand abstract figures in the same way that they are considered by Geometers when they assign motion to them . . .[17]

These properties (extension, mobility and impenetrability) correspond to those conditions in (1) and (2) on the previous page, and we are told that they do not constitute a physical body but only an abstract figure. What is required to make such an abstract figure a physcial body is the fulfillment of condition (3), i.e., "that . . . [it] . . . can excite various perceptions of the senses and the fancy in created minds." It no longer appears that the qualities which figure in scientific explanation are those that correspond to the causes of our perceptions. The causing of our perceptions is itself a quality over and above those qualities that are used in scientific explanation, though the presence of that quality marks our explanations as being about physical objects and not merely about abstract figures. The manner of this "causing" would appear then to be outside the realm of science, it being a product of God's will and requiring no mechanism, given Newton's account. Yet he describes these perceptions as caused by the motions of those abstract figures as in the quotation above. Newton thus indicates, somewhat inconsistently, that there may be some kind of mechanism. What could this mechanism be and how can we know anything of it? We seem to have no reason to think that change of color, for instance, is in any way related to any change of primary qualities. More importantly, the fact that I have any group of sensations does not even tell me whether any primary qualities exist and thus whether there is anything there. The situation is that there are two conditions that must be satisfied if something is to be a body, let us call them (a) and (b). Condition (a) is that there be extension, mobility and impenetrability. Condition (b) is that there be the power to produce sensations in us. Further all our knowledge comes via our sensations, they being "our sole judges in this matter."[18] Clearly I can tell if condition (b) is fulfilled, but this does not tell me that condition (a) is fulfilled. What is needed is some causal account that makes (b) the effect of (a) or some theological warrant in believing that God would not let (b) be fulfilled without (a) being fulfilled.

There does seem to be an intimation of a method of determining which are the primary qualities which may yield some hints as to the solution of this problem.

Newton expresses the view that in seeking the essential qualities of a substance through the method of abstraction one should only reject those qualities that could be removed from an object by natural causes.

> Clearly the changes which can be induced in bodies by natural causes are only accidental and they do not denote a true change of substance. But if any change is induced that transcends natural causes, it is more than accidental and radically affects the substance. And according to the sense of the demonstration, only those things are to be rejected which bodies can be deprived of, and made to lack, by the force of nature.[19]

There is an echo of this principle to be found in the Rules of Reasoning, Rule III, of the Principia, which states that, "The qualities of bodies, which admit neither intensification nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever."[20]

On the face of it then, both the "De gravitatione" and the Principia provide us with a principle that enables us to distinguish those qualities that are important to scientific explanation (the so-called primary qualities) from those that are not. We are in effect told to note which qualities remain under all natural transformations and to treat only those qualities as constituting body. We are also told what we will find if we make these observations, viz., extension, mobility, impenetrability and the ability to produce sensations in us. Thus the primary qualities are a subset of the qualities we perceive.[21] But the "De gravitatione" leaves matters rather more complex by its further distinction between the quality of having the power to cause sensations and the other qualities of extension, mobility and impenetrability.

Newton argues that God creates bodies in and "of" space through an act of will in the same way that we can move our bodies through an act of will. Although we do not know the mechanism whereby we accomplish this, we clearly believe that we do it. In the same way we can be assured that God creates objects in and "of" space despite our inability to conceive of any mechanism whereby this is done.

> Thus I have deduced a description of this corporeal nature from our faculty of moving our bodies, so that all the difficulties of the conception may at length be reduced to that; and further, so that God may appear (to our innermost consciousness) to have created the world soley by an act of will alone; and, besides, so that I might show that the analogy between the Divine faculties and our own is greater than has formerly been perceived by Philosophers.[22]

In the same way God bestows the power to stimulate the senses on these bodies.

> . . . I do not see that it would not equally operate upon our minds and in turn be operated upon, because it is nothing more than the product of the divine mind realized in a definite quantity of space. For it is certain that God can stimulate our perceptions by his own will, and thence apply such power to the effects of his will.[23]

The strong emphasis on the power of body to produce sensations in us, rather than, say, the "disposition" to do so, leads us to conclude that bodies are here conceived of as active rather than passive. This would, of course, strengthen the contrast Newton is making in the "De gravitatione" with Cartesianism in which matter is passive. This conclusion is strengthened by the fact that Newton claims to have reduced the problem of corporeal nature to the problem of how we move our bodies. This reduction was possible, he argues, because his description of body had been deduced from our faculty of moving our bodies. Corporeal body is then, for the Newton of this period, primarily active on analogy with the will of man and God. One can't help feeling that one has glimpsed the Leibnizian conatus in the following passage from "De gravitatione:"

> Thus you see how fallacious and unsound this Cartesian argument is, for when the accidents of bodies have been rejected, there remains not extension alone, as he imagined, but also the faculties by which they can stimulate perceptions in the mind and move other bodies.[24]

Though we have seen that Newton rests his argument in "De gravitatione" for God's will as the origin of the power of bodies to produce sensations on the power of the mind to move the body, I would like to suggest another source for this notion on the basis of the section on "Immagination & Phantasia & invention" in the "Quaestiones." We have seen that Newton there juxtaposes a reference to Glanvill's gypsy scholar and a description of an experiment on after images. A general feature of both of these items is a statement of the power of the will or imagination to produce thoughts, actions and sensations. Most importantly, Newton claims that the imagination or fancy can produce exactly the same sensations in us as the observation of an external object. It does this by affecting the spirits of the optic nerves in the same way that an external object would. The possibility of one person's imagination imposing these sensations on anothers mind is clearly suggested by the gypsy scholar story taken in conjunction with Newton's interpretation of his after image experiment. This ability to bind other minds to one's own is a matter of "heitning . . . [one's] fansie & immagination."[25] The imagination, we are told by Newton, is " . . . helped by good aire fasting moderate wine but spoiled by drunkennesse, gluttony, too much study . . ."[26] Thus the power of imagination can be strengthened or weakened. It is a short step from this to the positing of the infinite power of God's imagination and the possibility of all our sensations having their origins in God's imaginings. Newton does not, however, leave the matter there. God has the power to impart this ability to cause sensations and this he does, thereby creating physical bodies.

A kind of unity thus emerges. God can produce sensations, physical bodies can produce sensations, and we can produce sensations (as in the after image case). This unity appears to play an important part in Newton's thought during this early period. The existence of bodies of this sort clearly requires the existence of God, and the relationship between these notions of mind and body allows for a kind of interaction which Newton believes does not raise Cartesian problems. As Newton writes,

> . . . the usefulness of the idea of body that I have described is brought out by the fact that it clearly involves the chief truths of metaphysics and thoroughly confirms and explains them. For we cannot postulate bodies of this kind without at the same time supposing that God exists, and has created bodies in empty space out of nothing, and that they are beings distinct from created minds, but able to combine with minds.[27]

We shall later turn to the question of how this combining of minds and bodies takes place and whether the views on this matter expressed in "De gravitatione" are consistent with that expressed in the "Quaestiones." We must now, however, return to Newton's notion of active body and its analogical connection with the will of man and God.

If the power of bodies to cause sensations was merely and strictly a matter of will, and that not in the trivial sense in which everything can be said to be God's will, then no account could or need be given of a mechanism whereby bodies cause our sensations. In such a case the reason for the existence of primary qualities would be a religious mystery.[28] Newton tells us, however, that our perceptions are brought about by the motions of bodies. Which brings us back to the problem of how we are to relate the extension, motion and impenetrability of an object to the perceptions to which it gives rise. And of what do we predicate redness, loudness, etc.? Newton tells us that all we know of objects we know through the sensations they produce in us.[29] But if there is no causal connections between, say degree of extension and our perceptions, in what way can the one serve as a source of knowledge of the other? We have suggested that the only ways open seem to be to either provide a description of a causal mechanism that will serve as a basis for such causal inferences or to provide a theological warrant of the Cartesian sort. Newton seems to be presupposing the latter in his comparisons of the will of God and the will of man, but, as already mentioned, he does more than hint at the possibility of a causal account in attributing our sensations to the motions of bodies.

Any causal account of our perceptions that would incorporate the primary-secondary quality distinction as inherent in the view under discussion, would require a corpuscular theory, as argued in chapter I. Newton's corpuscularism dates from perhaps as early as 1661 as does his adoption of some form of the primary-secondary quality distinction.[30] Yet in "De gravitatione" he takes a position that appears to cut him off from any causal account that would make use of corpuscles.

In giving his description of bodies in "De gravitatione" Newton speaks of corpuscles as bodies,[31] but Newton's scheme makes the power to produce sensations an essential property of bodies and this does not seem to be a power that any single corpuscle can have. This then would leave us where we began, with abstract figures (which are apparently logical fictions for Newton)[32] as the causes of our perceptions. How can that which is neither body nor mind cause sensations? What is required then is that corpuscles be bodies and this requires that they have the power, individually, to produce sensations in us. I can find nothing in "De gravitatione" that would prove that Newton held that individual corpuscles could produce sensations. But in a letter sent to Oldenburg and dated 7, December 1675, which was six to ten years after the writing of "De gravitatione," Newton wrote,

> . . . it is not impossible but that microscopes may at length be improved to the discovery of corpuscles of bodies, on which their colour depends. For if those instruments could be so far improved, as with sufficient distinctness to represent objects five or six hundred times bigger than at a foot distance they appear to our naked eyes, I should hope, that we might be able to discover some of the greatest of those corpuscles. And by one, that would magnify three or four thousand times, perhaps they might all be discovered but those, which produce blackness.[33]

If we then allow Newton the existence of corpuscular bodies, one assumes that their properties will be only the primary ones and that it is through the motion of these corpuscles that our sensations are caused. Newton does not assert any of this in "De gravitatione" but his views there would seem to presuppose some such theory with the proviso that our corpuscles are bundles of qualities and not lumps of matter. But this is far too simplistic. It takes little thought to see that one could no more see a bundle of primary qualities than one could see a Platonic form. What would it be like, for instance, to see something that had no color but was extended? Newton perhaps saw this problem at the time of the writing of "De gravitatione" and so spoke of discovering corpuscles not "seeing" them and consciously chose not to explicitly state the theory of matter presupposed by what he did say. But if this is so what could he have meant by "discovering" corpuscles without a theory on which to base the required causal inference? In 1710 Newton published a short paper entitled "De natura acidorum"[34] in which a somewhat more complex theory of corpuscles and properties is presented, what we will call the theory of compositions. In the crucial passage Newton writes,

> We shall call particles of gold which mutually attract one another in the least quantity, particles of the first composition, and the sums of these particles-particles of the second composition, etc. Mercury and aqua regia can pervade only the pores between the particles of the last composition and none other.
>
> If any menstruum could pervade the particles of smaller compositions, or if the first and second compositions could be separated, gold might be turned into a fluid or at least be made softer; and if gold could once be made to ferment, it might be turned into another body.[35]

Newton further expounds on the theory of compositions in the thirty first Query of the Opticks, where he writes,

> Now the smallest Particles of Matter may cohere by the strongest Attractions, and compose bigger Particles of weaker Virtue; and many of these may cohere and compose bigger Particles, whose Virtue is still weaker, and so on for divers Successions, until the Progression end in the biggest Particles on which the Operations in Chemistry, and the Colours of Natural Bodies depend, and which by cohering compose Bodies of a sensible Magnitude.[36]

In the end, then, it was not the corpuscular atoms that could possibly be seen by use of the microscope but that which was the product of several compositions and indeed termed "the biggest Particles." For it was, according to Newton, these compounded particles that were the things upon which the color of bodies depended. We are then once again back at the beginning with admittedly imperceptible corpuscles as the ultimate constituants of perceptible bodies. These corpuscles, being imperceptible, are not bodies but at most abstract figures. The causal account has once again slipped through our fingers and our sensation-based inferences have gone with it.

We have defined the kernel of phenomenalism as the claim that the immediate objects of our perceptions are private sensations. It is quite clear from the foregoing that Newton shared this view with almost all his contemporaries. Metaphysical phenomenalism makes the additional claim that all statements about material objects are reducible to statements about our sensations. I hope that we have convincingly shown that Newton's view aims at such a position, albeit unsuccessfully. That Newton saw his attempt as unsuccessful is supported by the fact that he never again repeated it as a positive doctrine after the early period we have been considering.

My objection to this early theory of matter is based on the absence of a coherent and thus intelligible account of bridge principles. The theory of matter as it stands does not allow predictions in any strict sense. It must be admitted that in the view of many modern philosophers of science a causal account on which to base inferences is unnecessary.[37] I am not here arguing this point. It should be clear, however, that within the mechanistic framework of Newton and his contemporaries such a causal foundation <u>was deemed</u> necessary. Criticizing Newton's theory within the context of this belief is then revealing of his own struggles with what he took to be necessary for science. One can't help but feel that one has detected a deep-seated uneasiness in Newton's wavering between his attempts to indicate the existence of some kind of causal account and his phenomenalistic theory of matter. We will return to this problem again and again in the following chapters, but let us now return to Glanvill.

The Influence of Glanvill

In his Vanity of Dogmatizing, Glanvill considers a theory of perception and the relation of mind and body that is of some interest to our investigation. Although Descartes is clearly at the center of Glanvill's thought, Henry More's remedies to the Cartesian problems of interaction represent the most enticing of dogmas against which Glanvill is struggling. Glanvill studied with More and, at least at one time, found More's position convincing. Newton also found the Morean position enticing and although he, like Glanvill, ultimately rejected it, he retained a Morean outlook to the issues at stake and even retained a belief in some of the central doctrines such as the extension of spirit.

We will consider More's theory in some detail in the next chapter but at this point we will look at the tenets that Glanvill retains from the general theory.

The central core of the doctrine as accepted by

Glanvill is best summarized in the following passage from the Vanity:

> . . . the best Philosophy . . . derives all sensitive perception from Motion, and corporeal impress. . . . Not that the Formality of it consists in material Reaction, as Master Hobbs affirms, totally excluding any immaterial concurrence: But that the representations of Objects to the Soul, the only animadversive principle, are conveyed by motions made upon the immediate Instruments of Sense. . . . Thus the different effects, which fire and water have on us, which we call heat and cold, result from the so differing configuration and agitation of their Particles: and not from, I know not what chimerical beings, supposed to inhere in the objects, their cause, and thence to be propogated by many petty imaginary productions to the seat of Sense. So that what we term heat and cold, and other qualities, are not properly according to Philosophical rigour in the Bodies, their Efficients; but are rather Names expressing our passions . . . .[39]

Yet it is this "best Philosophy" that leads to the problems of scepticism.

> . . . it is conceiv'd to be as certain, as our faculties can make it, that the same qualities, which we resent [represent?] within us, are in the object, their Source. And yet this confidence is grounded on no better foundation, then a delusary prejudice, and the vote of misapplyed sensations, which have no warrant to determine either one or other. I may indeed conclude, that I am formally hot or cold; I feel it. But whether these qualities are formally, or only eminently in their producent; is beyond the knowledge of the sensitive.[40]

The doctrine does constitute, however, a basis for the attack on occult qualities that so characterizes the scientific revolution.

> Nor is the Aristotelian Philosophy guilty of this sloth and Philosophick penury, only in remoter abstrusities: but in solving the most ordinary causalities, it is as defective and unsatisfying. Even the most common productions are here resolv'd into Celestial influences, Elemental combinations, active and passive principles, and such generalities; while the particular manner of

> them is as hidden as Sympathies. And if we follow manifest qualities beyond the empty signification of their Names; we shall find them as occult, as those which are professedly so. That heavy Bodies descend by gravity, is no better an account then we might expect from a Rustick: and again, that Gravity is a quality whereby an heavy body descends, is an impertinent Circle, and teacheth nothing. The feigned Central alliciency is but a word, and the manner of it still occult. That the fire burns by a quality called heat; is an empty dry return to the Question, and leaves us still ignorant of the immediate way of igneous solutions. The accounts that this Philosophy gives by other Qualities, are of the same Gender with these: So that to say the Loadstone draws Iron by magnetic attraction, and that the Sea moves by flux and reflux; were as satisfying as these Hypotheses, and the solution were as pertinent. In the Qualities, this Philosophy calls manifest, nothing is so but the effects. For the heat, we feel, is but the effect of the fire; and the pressure we are sensible of, but the effect of the descending body. And effects, whose causes are confessedly occult, are as much within the sphear of our Senses; and our Eyes will inform us of the motion of the Steel to its attrahent. Thus Peripatetick Philosophy resolves all things into Occult qualities; and the Dogmatists are the only Scepticks.[41]

Glanvill puts forward the Cartesian mind-body duality as a truism and then points to the problem of interaction as the key epistemological difficulty. Although giving only short shrift to the solutions of Descartes and Kenelm Digby he devotes many pages to a consideration of the Morean solution through the notion of extended spirit.

On pages 28 and 29 Glanvill adopts the view that sensations are "made" by motions imprest on an ether ("Aethereall matter") and "carryed by the continuity thereof to the Common sense." But although he believes that the "ingenuity" of this view has won it a victory over others, he feels that there remain insuperable problems.

> For how the soule by mutation made in matter a substance of another kind, should be excited to action; and how bodily alterations and motions should concern it, which is subject to neither; is a difficulty which confidence may triumph over sooner, then conquer.[42]

The grounds for which problem he states as follows:

> For body cannot act on any thing but by motion; motion cannot be received but by quantative dimension; the soul is a stranger to such gross substantiality, and hath nothing of quantity, but what it is clothed with by our deceived phancies; and therefore how can we conceive under a passive subjection to material impressions?[43]

More's answer to these objections, as we shall see, is to claim that the soul is extended and thus does have something of quantity. Glanvill doesn't except this as a legitimate solution to his stated difficulties.

> Nor yet doth the ingenious hypothesis of the most excellent Cantabrigian Philosopher [More], of the souls being an extended penetrable substance, relieve us; since, how that which penetrates all bodies without the least jog or obstruction, should impress a motion on any, is by his own confession alike inconceivable. Neither will its moving the Body by a vehicle of Spirits, avail us; since they are Bodies too, though of a purer mould.[44]

Glanvill presents the further argument that this Morean union and motion of body and soul is unintelligible because " . . . there are not the least footsteps, either of such an Union, or Motion, in the whole circumference of Sensible nature: And we cannot apprehend any thing beyond the evidence of our faculties."[45]

Glanvill's claim is that anything which is conceivable is either "obvious to our senses" at present, or like something amongst our memories of past experience, or at least hinted at by our past or present, inward or outward, experience.[46]

More's answer is, of course, that we do have evidence of this "union or motion" every waking moment of our lives.

Glanvill's third objection is a rather curious one. The task of controlling the body in accordance with the Morean physiology is too complicated for the soul to achieve, especially given the fact of the autonomy of the will.

> . . . the . . . passages through which those subtill emmissaries are conveyed to the respective members, being so almost infinite, and each of them drawn through so many meanders, cross turnings, and divers roades, wherein other spirits are continually a journeying; it is wonderfull, that they should exactly perform their regular destinations without losing their way in such a wilderness . . .[47]

Yet it is clear that all of this takes place with regularity and according to a rule. But how could this be done, asks Glanvill. "That it is performed by meer Mechanisme, constant experience confutes; which assureth us, that our spontaneous motions are under the Imperium of our will."[48] Clearly then if it is done at all it is done by the soul, which must then keep track of each vein, muscle and artery of the body as well as " . . . the exact site, and position of them, with their severall windings, and secret chanels."[49] That the soul could do all this without our being aware of it, according to Glanvill, is absurd.

> Thus an Artist will play a Lesson on an instrument without minding a stroke; and our tongues will run divisions in a tune not missing a note, even when our thoughts are totally engaged elsewhere: which effects are to be attrib-

> uted to some secret Art of the Soul, which to us is utterly occult, and without the ken of our Intellects.[50]

Newton's specific objections to the Morean theory are nowhere made clear, but his own theory of the relation of mind and body implicit in "De gravitatione" does point at what he must have taken to be the deficiencies of More's theory. The central difference between them lies in the way that they consider matter. More's matter is a passive stuff, a substratum. Newton, on the other hand, sees matter as active and with a power to cause sensations in created minds, which power is itself akin to the power of the will to move the body. We have seen that Newton clearly thought that this notion of active matter would go a long way to solving the problems of interaction. If he believed that the Morean account did the job why would he have replaced it with his own distinctly idiosyncratic theory?

The fact that there is no hint of any rejection of the Morean account in the "Quaestiones" taken together with the implicit rejection in "De gravitatione" leads me to believe that Granvill's criticisms of More's theory ultimately convinced Newton. Granvill's criticisms rest ultimately on two points, (1) the inability of the soul to interact with gross passive matter, and (2) the absence of evidence for such a union.

It would seem that it was precisely on this first point that Newton rejected the Morean account. In fact it is almost solely on this point that the two theories differ. Newton retains More's subtle spirits, and indeed the entire Morean mechanism of sense perception. It is only on the question of the ultimate interaction of the subtle spirits with the soul in the sensorium that Newton differs with More by making matter actice rather than passive. In so far as an argument against Morean interaction is to be found in the "De gravitatione" it lies in Newton's "derivation" of active matter from sense experience.

We will return to the Newtonian theory of "De gravitatione" when we consider the influence of More. But I would like now to return to Glanvill and his extremely interesting notion of Adam as observer.

Glanvill presents the Adam of before the Fall as a kind of ideal observer. Since the Adam of before the Fall had all the perfections of which man is capable, he argues, all those means of perfecting the senses, e.g., telescopes, microscopes, etc., were unneeded.

> Adam needed no Spectacles. The acuteness of his natural Opticks (if conjecture may have credit) shew'd him much of the Coelestial magnificence and bravery without a Galileo's tube: And 'tis most probable that his naked eyes could reach near as much of the upper World, as we with all the advantages of art. It may be 'twas as absurd even in the judgement of his senses, that the Sun and Stars should be so very much, less then this Globe, as the contrary seems in ours; and 'tis not unlikely that he had as clear a perception of the earth's motion, as we think we have of its quiesence.
> Thus the accuracy of his knowledge of natural effects, might probably arise from his sensible perception of their causes. What the experience of many ages will scarce afford us at this distance from perfection,

> his quicker senses could teach in a moment. And whereas we patch up a piece of Philosophy from a few industriously gather'd, and yet scarce well observ'd or digested experiments, his knowledge was completely built, upon the certain, extemporary notice of his comprehensive, unerring faculties. His sight could inform him whther the Loadstone doth attract by Atomical Effluviums . . .[51]

All of which makes it sound as if there is a manifest experience, albeit not manifest to us, which allows for immediate knowledge of causes. Yet such a conclusion does not really do justice to Glanvill's position. In the Preface Glanvill deals with some objections he fears may be raised regarding the perfection of Adam's senses.

> . . . granting Adam's eye had no greater Diametrical wideness of the pupil, no greater distance from the Cornea to the Retiformis, and no more filaments of the Optick nerves of which the tunica Retina is woven, than we: the unmeasurable odds of Sensitive perfections which I assign him; will be conceiv'd mechanically impossible.[52]

Glanvill attempts to get round these objections by arguing that although the image on Adam's retina was the same as that on ours his critical faculties were so much better that he saw as through a telescope or microscope.

> For a little angle made in the Eye, will make as discernible an impression to a Soul of a greater Animadversive power, and assisted by more and meeter Instruments of sight; as a greater angle can make to a Soul of a less power, and destitute of those other Instruments, which are as necessary to sight as those Dioptrical conveniencies.[53]

But if the perfection of Adam's sensibility was a product of his critical faculties then we no longer are dealing with manifest experience but with the interpretation of sensation.

It would, however, be a mistake to take Glanvill's Adam too seriously. His function is not that of a piece of history, but as an ideal against which man's shortcomings are to be measured. But the quality being measured is not excellence of vision but the ability to acquire knowledge of the world through what is taken as the only possible method, that of empirical science. Adam, as ideal observer, is capable of knowing all that man ever could know but through his imperfections will never know. Why Adam then rather than God as the model of perfection? Precisely because Adam's knowledge must be obtained through sensation unlike God's whose omniscience is unconditioned. Adam knows the causes of gravity and magnetism through the sensations that mechanical causes produce in him. God simply knows how He made the world.

No such clear-cut notion of the ideal observer occurs in Newton's writings. The historical Moses would appear to have been all knowing in Newton's view, but this knowledge is seen as the gift of God and not the product of scientific enterprise. Newton held that the ancient world was full of active scientists of the very highest quality, however. He treats the Greek gods as historical figures whose scientific knowledge was in part responsible for their deification, but their role in Newton's writings is not that of the ideal observer.[54] They are taken as historical figures whose knowledge Newton was regaining through his own inquiries.

If anyone was for Newton an example of an individual who was, through his powers of observation and judgment, capable of knowing with certainty, it was Newton himself. This is not to say that Newton was Glanvill's Adam. For even in the heyday of Newton's self-confidence it was delimited by the dicta, "Hypotheses non fingo" (--certainty, yes, but not as to the causes--at least not yet!).

We turn now to a consideration of the influence of Henry More on the young Isaac Newton.

NOTES

CHAPTER VI

[1]The edition to which I will refer is Joseph Glanvill, _The Vanity of Dogmatizing: The three Versions_, ed. Stephen Medcalf, (Hove, Sussex: The Harvester Press, 1970). The reproduction of the _Vanity of Dogmatizing_ in this edition is that of the original 1661 edition from a copy in the London Library (shelf mark 45209).

[2]_Ibid_., p. 196. [3]_Ibid_., p. 197. [4]_Ibid_., p. 198.

[5]_Ibid_., pp 55-6, 59-60. [6]_Ibid_., p. 188.

[7]_Ibid_., p. 212.

[8]Isaac Newton, _Unpublished Scientific Papers of Isaac Newton_, eds. A. Rupert Hall and Marie Boas Hall, (Cambridge: Cambridge University Press, 1962), p. 138. "De gravitatione et aequipondio fluidorum" is a forty page MS in item Add. 4003 of the Cambridge University Library's Newton collection, a book the remainder of the pages of which are blank. All references will be to the translation in Hall & Hall.

[9]_Ibid_., p. 139.

[10]That Glanvill sees scepticism, of a sort, as the solution as well as the problem is shown in the following from page 223 of the _Vanity_:

The Sciolist may here see, that what he counts of all things most absurd and irrational, hath yet considerable shew of probability to plead its cause, and it may be more then some of his presumed demonstrations. 'Tis irreprehensible in Physitians to cure their Patient of one disease, by casting him into another, less desperate. And I hope, I shall not deserve the frown of the Ingenuous for my innocent intentions: having in this only imitated the practice of bending a crooked stick as much the other way, to straighten it. And if by this verge to the other extream, I can bring the opinionative Confident but half the way, viz. that discreet modest aequipoise of Judgement, that becomes the sons of Adam; I have compast what I aim at.

[11]"De gravitatione," p. 144.

[12]Hobbes argued that to be real was to be extended. More, accepting this view, then argued that God and spirit being real must be extended.

[13]"De gravitatione," p. 140. [14]Ibid., p. 143.

[15]Ibid. [16]Ibid. [17]Ibid., p. 122.

[18]Ibid., p. 139. [19]Ibid., p. 146.

[20]Isaac Newton, Mathematical Principles of Natural Philosophy, trans. Andrew Motte, rev. and ed. Florian Cajori, (Berkeley, Calif.: University of California Press, 1947), p. 398.

[21]Strictly, for Newton, we do not perceive extension but a degree of extension, nor motion but a degree of motion, nor the power of objects to produce sensations but only the sensations. From these, however, we can infer the primary qualities.

[22]"De gravitatione," p. 141. [23]Ibid., p. 139.

[24]Ibid., p. 147. [25]"Quaestiones," folio 109r.

[26] *Ibid.* [27] "De gravitatione," p. 142.

[28] God, after all, moves in mysterious ways!

[29] "De gravitatione," p. 139.

[30] We have seen that both of these doctrines appear in the "Quaestiones" sometime between 1661 and 1665.

[31] On page 139 of "De gravitatione" Newton writes, "In the same way if several spaces of this kind should be impervious to bodies and to each other, they would all sustain the vicissitudes of corpuscles and exhibit the same phenomena."

[32] Newton writes on page 140 of "De gravitatione," "These things [that fulfil his three conditions] will not be less real than bodies, nor (I say) are they less able to be called substances. For whatever reality we attribute to bodies arises from their phenomena and sensible qualities."

[33] Isaac Newton, "Discourse of Observations," in *The History of the Royal Society of London*, Thomas Birch (London, 1756-7), vol. III, p. 303.

[34] "De natura acidorum" was written in 1692 but not published until 1710 in the Introduction to Vol. II of the *Lexicon Technicum* of John Harris. The paper is republished in *Isaac Newton's Papers & Letters on Natural Philosophy*, ed. I. Bernard Cohen (Cambridge: Cambridge University Press, 1958), pp. 255-8. References will be to the Cohen edition.

[35] *Ibid.*, p. 257. [36] *Opticks*, p. 394.

[37] Quine, et. al. For an interesting new approach to

this issue see Roy Bhasker, A Realist Theory of Science, (Bristol: Leeds Books Ltd., 1975).

[38]See chapter VII. [39]Vanity, pp. 87-8.

[40]Ibid., p. 89. [41]Ibid., pp. 170-2.

[42]Ibid., p. 29. [43]Ibid. [44]Ibid., pp. 22-3.

[45]Ibid., p. 24. [46]Ibid., pp. 23-4.

[47]Ibid., p. 24. [48]Ibid., p. 25. [49]Ibid.

[50]Ibid., p. 26. [51]Ibid., p. 5-6.

[52]Ibid., Preface. [53]Ibid.

[54]In The Chronology of Antient Kingdoms Amended, published by Samuel Horsley in his Opera Quae Exstant Omnia (of Isaac Newton) vol. V, (London, 1785), and reprinted by Friedrich Frommann Verlag (Stuttgart-Bad Cannstatt, 1964), Newton writes on page 281, as part of the entry for the year 939 B.C., "Chiron, who was born in the golden age, forms the constellations for the use of the Argonauts; and places the solsticial and equinoctial points in the fifteenth degrees or middles, of the constellations of Cancer, Chelae, Capricorn, and Aries." On page 280, he writes, "Sesac, from his making the river Nile useful by cutting channels from it to all the cities of Egypt, was called by its names, Sihor or Siris, Nilus, and AEgyptus. The Greeks, hearing the Egyptians lament O Siris and Bou Siris, called him Osiris and Busiris."

CHAPTER VII

NEWTON AND MORE

Henry More is mentioned twice in the "Quaestiones." The first reference is on folio 89r wherein Newton argues for atomism.

> And y^{t} matter may be so small as to be indiscerpible the excellent D^{r} Moore in his booke of y^{e} soules immortality hath proved beyond all controversie . . .

The second reference is on folio 108r where "D^{r} Mores immort:" is refered to again. Half of this folio is devoted to notes from More's <u>The Immortality of the Soule</u> (London, 1659), page 255.

The following is the first half of folio 108r:

> Of Memory
>
> Messala Corvinus forgot his owne name. One by a blow wth a stone forgot his mothers name & kinfolkes. A young student of Montpelier by a wound lost his memory so y^{t} he was faine to be taught y^{e} letters of y^{e} Alphabet againe. The like befell a Franciscan frier after a fever Thucidides writes of some who after theire recovery from y^{e} greate pestilence of Athens forgot y^{e} names & persons of their freinds & themselves too not knowing who they were or by w^{t} names they were called:
>
> Atque etiam quosdam cepisse oblivia rerum
> Cunctarum, neque se possent cognoscere ut ipsi.
>
> Dr Mores immort:

The above is clearly a paraphrase of the following sections of More's <u>The Immortality of the Soule</u>:

> And yet that Diseases and Casualties have even utterly taken away all memory, is amply recorded in History. As that Messala Corvinus forgot his own name; that one, by a blow with a stone, forgot all his learning; another, by a fall from an Horse, the name of his Mother and kinsfolks. A young Student of Montpelier, by a wound, lost his Memory so, that he was fain to be taught the letters of the Alphabet again. The like befell a Franciscan after a Feaver. And Thucydides writes of some, who after their recovery from the great Pestilence at Athens, did not onely forget the names and persons of their friends, but themselves too, not knowing who themselves were, nor by what name they were called:
>
> Atque etiam quosdam cepisse oblivia rerum
> Cunctarum, neq; se possent cognoscere ut ipsi;
>
> as the Poet Lucretius sadly sets down in his description of that devouring Plague, out of the fore-named Historian.[1]

Although there are only these two specific references to the name of Henry More, a larger proportion of the "Quaestiones" is given over to his work, The Immortality of the Soule, than any other work or author but Robert Boyle.

The entirety of folio 104r of the "Quaestiones" consists of paraphrases from the Immortality. The following is the content of folio 104r. The numerals to the left of the text are added to simplify future reference.

Of Sensation

The senses of divers men are diversly affected by y^{e} same objects according to y^{e} diversity of theire constitution
To them of Java pepper is cold.
If y^{e} orifice of y^{e} stomch be wounded it sooner dispatches a man y^{n} if y^{e} head: y^{e} former having greate sympathy wth y^{e} heart dea'ds [?] it & stops it motion & so sence ceaseth: y^{e} latter though it take away sence yet y^{e} hearts motion is not impeded thereby.
The Common sensorium is either 1 y^{e} Whole body 2 y^{e} orifice of y^{e} stomach 3 y^{e} heart 4 y^{e} braine

orifice of y^{e} stomach 3 y^{e} heart 4 y^{e} braine 5 y^{e} membranes 6 y^{e} septum lucidum 7 some very small & perfectly solid particle in y^{e} body 8 y^{e} Conarion 9 y^{e} Concurse of nerves about y^{e} 4th ventricle of y^{e} braine 10 the animal spirits in y^{t} 4th ventricle.

A ligature being tied sence & motion will be twixt y^{e} ligature & y^{e} head but not downwards.

A frogs braine being peirced it looseth both sense & motion but it will leape & have its sence though its bowells bee taken out.

Phisitians find y^{e} causes of lethargies Apoplexies Epilepsies etc. diseases y^{t} seiz on y^{e} Animal functions in y^{e} head.

Unles y^{e} braine be peirced so deepe as to reach y^{e} ventricles y^{e} wound will not take away sence & motion

A man cannot see through y^{e} hole w^{ch} a trepan makes in his head. Stones have beene found in y^{e} glandula pinealis & it is environed with a net of veines & arteries.

A Vertigo must be from y^{e} turning round of y^{e} spirits

The least weight upon a mans braine when hee is trepanned maketh him wholly devoyd of sensation & motion

The above derives from the following pages of the <u>Immortality</u>: lines 5-9 from page 187, lines 10-16 from pages 155-6, lines 17-18 from pages 190-1, lines 19-21 from page 191, lines 22-4 from page 191, lines 25-6 from page 192, lines 27-8 from page 193, lines 28-30 from page 197, and lines 31-2 from pages 203-4. The extensive paraphrasing of More and the obviously close reading of him by Newton taken together with the fact that Newton's own theory of sensation indicated in the "Quaestiones" and "De gravitatione" is very close to that of More would seem to prove that Newton's theory is derived from that of More.

Another paraphrase of More's <u>Immortality</u> is of an apparently trivial observation concerning snails:

> When a snaile creeps a gale of spirits ciruit from her head downe her back to her taile & up her belly to her head againe.[2]

Which in More reads,

> And to make yet a step further, That ocular demonstration that Henricus Regius brings Philos. Natur. lib. 4. cap. 16. seems to me both ingenious and solid. It is in a Snail, such as have no shells, moving in a glass: so soon as she begins to creep, certain Bubbles are discovered to move from her tail to her head; but so soon as she ceases moving, those Bubbles cease. Whence he concludes, That a gale of spirits that circuit from her head along her back to her tail, and thence along her belly to her head again, is the cause of her progressive motion.[3]

More took this demonstration of the snail to be an "ocular demonstration" of the role of animal spirits in sensation. This is surely what interested Newton and not some odd fact about snails. In a book published in 1664 Henry Power wrote the following:

> Nay further (which is the best Remarkable of all) this juice [nutritive humour] hath not onely a circular motion; but also the very Animal Spirits (by which she moves)seem to have the like Circulation. For, if you observe her with the bare eye to creep up the sides of a glass, you shall see a little stream of clouds, channel up her belly from her tail to her head, which never return again the same way, but probably go backwards again from the head down the back to the tail; and thus, so long as she is in local motion they retain their circulation, which is a pleasant spectacle . . . . which handsome experiment does not onely prove the Spirits circular motion, but also ocularly demonstrates that the Animal Spirits are the Soul's immediate instrument in all Loco-motion . . . . it is far more ingenious to believe it to be a gale of Animal Spirits, that, moving from her head along her back to her tail, and thence along her belly to her head again, is the cause of her progressive motion.[4]

Here too the observation concerning the snail is termed an "ocular demonstration." There is little doubt that Power had read More's The Immortality of the Soule, since it is mentioned by him several times. Power's book, Experimental Philosophy, in Three Books: containing New Experiments Microscopical, Mercurial, Magnetical (London, 1664) was read by Newton shortly after the period we have been considering. Although there is to my knowledge no explicit reference to Power in any Newton manuscript, I have determined that notes taken from Power's section on magnetism do occur in MSS Add. 3974, bundle 1, folio 1v of the University Library, Cambridge, Newton Collection. These notes very likely date from the year 1667.

More's name has occured many times throughout the preceding pages and his general importance to Newton's early development should already be clear. It remains, however, to look at the specific doctrines regarding sensation and the relation of mind and matter which he put forward in the Immortality and to look at Newton's reactions to them.

The Immortality of the Soule is meant to be a a refutation of the Hobbesian doctrines concerning body and mind. The refutation is centered in what must be considered a Cartesian framework with one major exception. This exception lies in More's definition of mind and matter and is itself a product of More's acceptance of the Hobbesian identification of existence and spatiality. Mind or spirit is, since it exists, extended, according to More. What then is the difference between mind and matter if they are both extended? Mind or spirit is penetrable and indiscerptible, whereas matter is impenetrable and discerptible. Further, mind or spirit is active whereas matter is absolutely passive. In this way Cartesian dualism is retained with all its problems of interaction. Mind, being extended, can now occupy the same space as the body which contains it but their contact is not of the sort that could allow direct causal interaction since the two things in contact are still fundamentally different in nature. An intermediary is required and this More attempts to supply in the notion of animal spirits which are not spirits in the same sense that mind and God are, but, rather in the sense that it is a very diffuse matter that is so thin it is almost like spirit. The soul though distributed throughout the body has its seat of activity in the brain. To it are transmitted those motions caused by external objects interacting with our bodies. The means of transmission are once again the spirits which fill the nerves which lead from the organs of sense to the fourth ventricle of the brain, the seat of the soul, the common sensorium.

> I say in general, That sensation is made by the arrival of motion from the Object to the Organ; where it is received in all the circumstances we perceive it in, and conveyed by vertue of the Souls presence there, assisted by her immediate Instrument the Spirits, by vertue of whose continuity to those in the Common Sensorium, the Image or Impress of every Object is faithfully transmitted thither.[5]

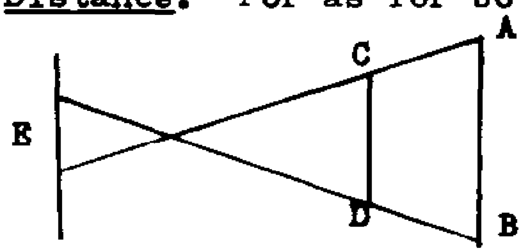
More presents many arguments to support his anti-Hobbesian contention that matter cannot have sensation. His main argument for this claim is of special interest to us in that it illucidates his general views regarding the relation of mind and body.[6]

The form of the argument is modus tollens; we start with the assumption that the common sensorium (mind) is a part of matter and examine the possible consequences of such an hypothesis, when the consequences are shown to be false we shall have established that the common sensorium is not material. The possible consequences are (1) that one point of the material common sensorium receives the whole image of an observed object, (2) that each point of the material common sensorium receives a whole image of the object, or (3) that each part of the sensorium receives a part of the observed object with the totality of parts receiving the totality of the image.

Since the common sensorium (mind) is also that which causes the motion of our bodies the single point of (1) would, through its motion, have to cause the motion of the millions of points of matter that constitute our bodies and this we know cannot be done, for nowhere in nature do we see such a thing occur. (2) is shown false through a consideration of its own strange consequence; that if each point sees the whole object then I should see a cluster of objects. But if I only see one and I am identical with my common sensorium then " . . . I be one of these points, what becomes of the rest? or *who* are they?"[7] The third is shown false by its contradicting our experience of the unity of objects, " . . . for we finde our selves to perceive the whole Object, when in this case nothing could perceive the whole, every part onely perceiving its part . . ."[8] The common sensorium is then not a part of matter but a spiritual substance which is said to perceive those objects that produce motions transmitted to the fourth ventricle of the brain by the animal spirits as unities.

How the motion of the animal spirits are "translated" by the soul into sensations (or images) is not described by More but in an interesting discussion of memory some possible hints are given.

More argues that memory cannot be a matter of marks in the brain, for our memories are more comprehensive than could ever be accounted for by any possible number of marks.

> . . . we remember some things, of which there can be no *Signatures* in Matter to represent them, as for example, *Wideness* and *Distance*. For as for both of them, there is no note can be made in the Matter E, by lines from the two Objects A.B. and C.D.
>
> 
>
>
> whereby the difference of remoteness of A.E. above C.E. or of the wideness of A.B. above C.D. can be discerned; for both the Objects make one and the same signature in the matter E.[9]

He concludes that memory is in the soul and animal spirits and not the brain but writes on page 229,

> If there be any <u>Marks</u> in it, it must be a kind of <u>Brachygraphie</u>, some small dots here and there standing for the recovering to Memory a series of things that would fill, it may be, many sheets of paper to write them at large. As if a man should tie a string about a friends finger to remember a business, that a whole daies discourse, it may be, was but little enough to give him full instructions in. From whence it is plain that the <u>Memory</u> is in the Soule, and not in the <u>Brain</u>. And if she doe make any such Marks as we speak of, she having no perception of them distinct from the representation of those things which they are to remind her of, she must not make them by any <u>Cognitive power</u>, but by some such as is Analogous to her <u>Plastick Faculty</u> of organizing the Body, where she acts and perceives it not.

More thus argues that if there are "marks" in the brain which are an aid to memory they are a kind of shorthand in which a little stands for a lot. But he then identifies this with the far different device of tying a string about one's finger. In a shorthand specific symbols represent specific linguistic entities, whether they be syllables, words, or phrases. The specific symbols retain their reference through different uses. The piece of string does not function in this way at all, being a symbol that changes its referent from use to use. Further he argues that since we do not perceive these marks but only the things that they represent they must be made by us unconsciously.

The most telling objection against the idea that memory proceeds from marks in the brain forming a kind of shorthand, is not made by More, but appears at the bottom of folio 108r of Newton's "Quaestiones," the same folio that contains paraphrases of More on memory: "If memory bee done by characters in y^e braine yet y^e soule remembers too, for shee must remember those characters." And again on folio 130v,

> Memory is a faculty of the soule (in some measure) for else how can divers sounds, or words excite her to divers thoughts-or 3 4 5 or more words beget the same thoughts in her. Perhaps she remembers by the helpe of characters in the Braine, but then how doth she remember the signification of those characters.

To answer that we remember those marks by other marks leads to an infinite regress, whereas to leave it as it stands shows that the notion of marks lends nothing to the explanation of memory.

Most crucially, if anyone held a theory in which marks in the brain acted as some intermediate step between objects and the soul's perception of them, the same objections would apply. Now although More sidesteps the questions of whether in fact images are formed in the brain, Newton clearly did believe that they were, at least in his early years and probably later. In folio 130v we have seen the following queries and responses:

> Quae 1 Why objects appear not invert, Resp: The mind or soule cannot judge the image in the Braine to be inverted unlesse shee perceived externall things-with which shee might compare that Image:
>
> 2. Why doe appeare to bee without our body? -Resp: Because then in the image of things delineated in the braine by sight, the bodys image is placed in the midst of the images of other things, is moved at our command towars & from those other images, etc:
>
> 3. But why are not these objects then judged to bee in the braine Resp: Because the image of the brain is not painted there, nor is the Braine perceived by the soule it not being in motion, & probably soule perceives noe bodys but by the helpe of their motion.

> But were the Braine perceived together with those images in it wee should thinke wee saw a body like the braine encompassing & comprehending our selves the starrs & all other visible objects. etc:

We have already argued, in chapter III, that Newton in fact did continue to hold a form of this theory to the end of his life. One might argue that despite Newton's statement of an objection to a mark in the brain theory of memory that could have been equally applied to a mark in the brain theory of perception, he did not make the connection. Although this is possible it is made all the more unlikely by the fact that such an objection was raised by Glanvill in his Vanity which we have established was carefully read by Newton. Glanvill writes,

> Some say, that the soul indeed is not passive under the materiall phantasms; but doth only intuitively view them by the necessity of her Nature, and so observes other things in these there representatives. But how is it, and by what Art doth the soul read that such an image or stroke in matter [whether that of her vehicle, or of the Brain, the case is the same] signifies such an object? Did we learn such an Alphabet in our Embryo-state?[10]

One must ask the question, Why did Newton continue to hold a theory to which he himself saw the major objections? We will have to consider a possible answer to this question in the last chapter.

The phenomenalistic elements in Newton's early thought were not without their precursors in the writings of Henry More. In More's Immortality we find the following "Axiome VIII:"

> The Subject, or naked Essence or Substance of a thing, is utterly unconceivable to any of our faculties.[11]

In justification of which he states, " . . . that if he take away all Aptitudes, Operations, Properties and Modifications from a Subject, that his conception thereof vanishes into nothing, but into the Idea of meer Undiversificated Substance; so that one Substance is not then distinguishable from another, but onely from Accidents or Modes, to which properly belongs no subsistence."[12]

It is a very tenuous thing indeed that is left to subsist under the aptitudes, operations, properties and modifications of bodies. I feel quite certain that Newton in reading the above passage found nothing at all under those properties.

The next "Axiome" is even more important to our inquiry. More writes,

> Axiome IX
>
> There are some Properties, Powers and Operations, immediately appertaining to a thing, of which no reasons can be given, nor ought to be demanded, nor the Way or Manner of the cohaesion of the Attribute with the Subject can by any means be fancyed or imagined.[13]

We have seen that in "De gravitatione" Newton does away with the notion of matter as a cause of the properties of an object, describing the matter ironically as a "certain unintelligible reality." Body is for him an extended region of space that has the power to produce certain sensations in us. The question of whether or not the mechanism of this power is determinable has been discussed. In fact in the above

Axiome IX we have a basis for the claim that any such account could never be forthcoming. As More says in defence of his Axiome IX, "For if the naked substance of a Thing be so utterly unconceiveable, there can be nothing deprehended there to be a connexion betwixt it and it's first Properties."[14] We have already argued in much the same way on pages 104-108, but just as Newton apparently went beyond his own principles to a statement about the causes of our sensations, so More in his Axiome X gives us a principle that violates Axiome IX.

> Axiome X
>
> The discovery of some Power, Property, or Operation, incompetible to one Subject, is an infallible argument of the existence of some other, to which it must be competible.
>
> 13. As when Pythagoras was spoken unto by the River Nessus, when he passed over it, and a Tree by the command of Thespesion the chief of the Gymnosophists saluted Apollonius in a distinct and articulate voice, but small as a womans; it is evident, I say, That there was something there that was neither River nor Tree, to which these salutations must be attributed, no Tree nor River having any Faculty of Reason nor Speech.[15]

There are at least two problems with this Axiome and its attendant supportive statement. How is compatibility to be established? If it is merely a matter of past experience then surely we do not have an "infallible argument" for the existence of another subject. Furthermore there is the supposition that all subjects have appropriate powers, properties and operations. In what could this appropriateness lie if there is no way that "the cohaesion of the Attribute with the Subject can by any meanes be fancyed or imagined." To say that no river or tree has the faculty of reason is to make a judgment about what attributes can reside together, not an experiential judgment merely about what attributes do reside together, for that would clearly be ad ignorantium.

We should not be surprised by this transgression of self-drawn boundaries by both More and Newton for it seems to be the rule rather than the exception; note Locke and Kant, for instance. But one should in each such case seek the supposed ground for such transgressions and it is just this that we are doing for the case of Isaac Newton.

NOTES

CHAPTER VII

[1]Henry More, The Immortality of the Soule, So farre forth as it is demonstrable from the Knowledge of Nature and the Light of Reason, (London, 1659), p. 255.

[2]"Quaestiones," folio 117r.

[3]Immortality, p. 203.

[4]Henry Power, Experimental Philosophy, in Three Books: containing New Experiments Microscopical, Mercurial, Magnetical, (London, 1664), pp. 38-9.

[5]Immortality, p. 228. [6]Ibid., pp. 129-30.

[7]Ibid., p. 130. [8]Ibid. [9]Ibid., p. 132.

[10]Vanity, pp. 29-30. [11]Immortality, p. 10.

[12]Ibid., p. 11. [13]Ibid. [14]Ibid.

[15]Ibid., p. 15.

CHAPTER VIII

NEWTON AND BOYLE

Reading Boyle

There remains only one more figure that we must consider before we draw together the many strands that we have put down and attempt to answer the numerous questions we have raised.

Robert Boyle was mentioned in the early pages of this work as being one of the important influences on Newton. There are fully twenty seven entries of works by Boyle in the Musgrave-Huggins' List. This was far and away the largest collection of books by a single author in Newton's library.

During his school years (1661-1665) Newton read three of Boyle's works: New Experiments Physico-Mechanicall touching the Spring of the Air, The Experimental History of Cold Begun and Experiments and Considerations touching Colours or An Experimental History of Colours Begun.[1] The last of these led to Newton's own work on colors during the year 1665/66. The degree of continuity between Newton's notes from Boyle's History of Colours and his later work was so great as to mislead A. R. Hall into believing that they were in fact notes of Newton's own experiments regarding color.[2]

By 1673, the year after Newton had begun to have the results of his optical experiments published in the Transactions of the Royal Society, he had won sufficient regard from Boyle to be the recipient of a presentation copy of Boyle's Several Tracts of the strange Subtility, Efficacy and determinate Nature of Effluviums, of New Experiments to make the parts of Fire and Flame Stable and Ponderable; together with some Additional Experiments about Arresting and Weighing of Igneous corpuscles; as also a Discovery of the Perviousness of Glass to Ponderable parts of Flame, with some Reflexions on it by way of Corollary (London, 1673). The copy of the book was sent by Henry Oldenburg, the Secretary of the Royal Society, accompanied by a letter in which he writes,

> I herewith send you Mr. Boyle's new Book of Effluviums, wch he desired me to present to you in his name, wth his very affectionat service, and assurance of ye esteem he hath of your vertue and knowledge.[3]

From that point onward there were occasional meetings at which scientific matters were discussed. There was in addition a correspondence, though not a heavy one, between the two men. That Boyle held a special place in Newton's estimation is perhaps best seen in the fact that Newton, in a letter written to Boyle on February 28, 1678/9, communicated to him material of so speculative a nature (by Newton's standards) that it was not to see the light of day until the publication of the Query 18 of the Opticks.

> Honoured Sr
> I have so long deferred to send you my thoughts about ye Physicall qualities we spake of, that did I not esteem my self obliged by promise I think I should be ashamed to send them at all. The truth is my notions about things of this kind are so indigested yt I am not satisfied my self in them, & what I am not satisfied in I can scarce esteem fit to be communicated to others, especially in natural Philosophy where there is no end of fansying.[4]

In 1687 Newton had a presentation copy of the Principia given to Boyle. In a letter dated July 5, 1687 Halley writes to Newton,

> I have at length brought your Book [the Principia] to an end, and hope it will please you. The last errata came just in time to be inserted. I will present from you the books you desire to the R. Society, Mr. Boyle, Mr. Pagit, Mr. Flamsteed and if there be any else in town that you design to gratifie that way . . .[5]

In returning to Newton's student years we look once again to the "Quaestiones" for indications of Boyle's early influence.

There are six explicit references to Boyle in the "Quaestiones" and the single largest section of the "Quaestiones," "Of Colours," consists almost entirely of paraphrases from Boyle's History of Colours.[6]

Let us begin with what was apparently the first of Boyle's works read by Newton, New Experiments Physico-Mechanicall touching the Spring of the Air.

On folio 90v of the "Quaestiones" we find the following:

> Wither it be from y^e close crowding of all y^e matter in y^e world affirmated. For y^e aire (though its pressure bee but little in respect of y^t, performed by y^e purer matter of y^e vortex (twixt ☉ & us) receeding from ye center) by its pressure to y^e center & consequently crowding all thing close together betwixt w^{ch} there is not aire to keepe ȳ sides of 2 marbles y^e [illegible] of water etc but this juncture can̄ot be very firme by reason y^t y^e pressure of y^e aire is not verry strong as appeares by y^e experiments of Eqe Boyle.

This appears strange at first since we generally think of Boyle as demonstrating the great pressure exerted by air, but another of his purposes was to show that a vacuum could exist. To this end he several times argues that the force of air is less than that which would be expected if nature did in fact abhor a vacuum.

> And to evince, that these phenomena were the effects of a limited and even moderate force, and not of such an abhorrency of a vacuum, as that to avoid it, many have been pleased to think, that nature must, upon occasion, exercise an almost boundless power; we afterwards purposely tried this experiment with several glasses somewhat thicker than those phials, and found the event to verify our conjecture, that it would not succeed; for the glasses were taken out as entire as they were put in.[7]

On folio 106r of the "Quaestiones" there is a reference to a specific experiment,

> Sounds are much fainter in y^e exhausted receiver then in the open Aire. Boyle Exper 27

In Experiment XXVII, pp. 62-4, Boyle describes various experiments conducted with his receiver to test whether sound is propagated by means of the air. Having placed an open watch within the receiver and noted that the watch could be heard when the air was not pumped out of the receiver, he proceeded to remove the air. Boyle records on page 62, "The pump after this being employed, it seemed, that from time to time the sound grew fainter and fainter . . ." Further, on the next page Boyle writes,

> On the occasion of this experiment concerning sounds, we may add in this place, that when we tried the experiment formerly mentioned, of firing gunpowder with a pistol in our evacuated receiver, the noise made by the striking of the flint against the steel was exceeding languid, in comparison of what it would have been in the open air. And on divers other occasions it appeared, that the sounds created within our exhausted glass, if they were not lost before they reached the ear, seemed at least to arrive there very much weakened.[8]

A copy of the Oxford, 1660 edition of <u>New Experiments Physico-Mechanicall touching the Spring of the Air</u> was in Newton's library, which copy is now in the Newton Collection of Trinity College, Cambridge (shelf mark NQ. 10. 69). Newton made no marginal notes in this copy though there is some dog-earing to technical information on how to reproduce the experiments.[9]

We will return to Boyle's <u>Spring of the Air</u> after determining which others of Boyle's works were read by Newton during the period 1661-1665.

On folio 96v, "Of heate & Cold," of the "Quaestiones" we find the following:

1 Snow put in a glasse & salt or any quick dissolvent put into it & well mixed wth it will cause vapors to settle on y^{e} outside of y^{e} glase & to freeze
2 [illegible] warme water or heated sand powered [powdered] into y^{e} snow and well shaked together will condense vapors on y^{e} outside & perhaps congeale y^{m}. M^{e} Boyle
3 Cold (because bodys condensed therewth moves down-

wards) tends farthest downwards as heat upwards.

4 Tis best to freze liquors at y^e bottome for fear of breaking y^e glasse.

5 An frozen egg will thaw much faster when immersed in water y^n w^n in y^e ayre, & will freze y^e water by its thawing. Soe will frozen [illegible] chese, meats, glasse.[10]

I have traced each of these to passages in Boyle's <u>The Experimental History of Cold Begun</u>.[11] Paragraph 1 is a paraphrase of material to be found on pp. 509-10 of that work.

> . . . we shall here observe once for all, that the snow or ice included, together with the saline ingredient (whatever that were) was always thawed within the glass: and that consequently, it was the condensed vapour of the air, or other liquid that adhered to the outside of the glass, which was turned into ice . . .

Paragraph 2 is a paraphrase of material to be found on p. 512.

> 1. Into a single phial almost filled with snow, there was poured a pretty quantity of well-heated sand, that it might dissolve the snow in many places at once, without heating the ambient air, or the outside of the glass: but though the solution of the snow seemed to succeed well enough upon the shaking of the vessel, yet the outside of the glass was only bedewed, not frozen.
> 2. Into another single phial almost filled with snow, we poured some water, which we judged of a convenient warmth, . . . and taking a convenient time to shake the glass, we did by this way produce a very considerable degree of cold, and much dew on the outside, but were not satisfied, that any of the dew was frozen. . .

Paragraph 3 is a paraphrase of material to be found on p. 524.

> . . . the notes seem to persuade it, that the tendency of the cold produced by bodies qualified to freeze others is greater downwards than upwards . . .

Paragraph 4 is a paraphrase of material to be found on pp. 525-6.

> The consideration of this invited me to alter the common way of freezing, and order the matter so, that whensoever I pleased, the exposed liquor should not begin to

> freeze at the top or sides, but at the bottom . . . without danger of breaking the vessel . . .

The first sentence of paragraph 5 can be traced to pp. 527-8.

> We afterward repeated the experiment of laying two frozen eggs near together . . . the one under water, and the other out of it, till that put in water had got a thick icy crust, and by breaking of them both, presently after one another, were confirmed in the persuasion, that frozen eggs will thaw by great odds (caeteris paribus)faster when immersed in water, than when surrounded only with air.

Finally, the second sentence of paragraph 5 comes from p. 529.

> . . . I have been assured by one . . . that a great cheese he immersed in water in a cold country, was presently covered with ice . . . . some glasses, newly brought from the shop, and not imployed, lying in a basket, as they poured water into one of them to rince it, part of it was presently turned into ice . . .

The section "Of heate & Cold" of the "Quaestiones" continues on folio 97v and all of it may, like the foregoing, be traced directly to Boyle's History of Cold.[12]

A copy of Robert Boyle's New Experiments and Observations touching Cold or an Experimental History of Cold Begun (London, 1665) was owned by Newton and that copy is now in the Newton Collection of Trinity College Library, Cambridge (shelf mark NQ. 8. 126). Like Newton's copy of The Spring of the Air it is without marginal notes but there is a great deal of dog-earing throughout. A question may arise concerning the late date of the publication of Boyle's History of Cold, 1665, and our claim that the "Quaestiones" dates entirely from the period of 1661-1665. The book was published and available, however, early in 1665 and it is possible, though unlikely, that Newton was able to obtain a large part of it late in 1664 prior to its publication. In either case it was quite possible for Newton to read and make notes from the book prior to his departure from Cambridge at the end of the Michaelmas term, 1665. In the publishers Advertisement, "The Publisher to the ingenious Reader," we find the following concerning the date of publication and availability of the book: " . . . the author . . . did in the first or second week of the frost, which was about the end of the year 1664, present the Royal Society with divers copies of the History of Cold, though the the book were not then quite printed off. . . . And finding the frosty weather to continue later than was expected, (which had he foreseen, before his history was printed off, it would have given him opportunity of enlargements) he hopes the publication may not be yet too late for diligent readers, to make some use of the season for examining his experiments, or trying some of the new ones, those may suggest."[13]

The third and final work of Boyle's that I have been able to trace from Newton's comments in the "Quaestiones" is Experiments and Considerations touching Colours or An Experimental History of Colours Begun (London, 1664). Although no copy of this book appears on the Musgrave-Huggins' List nor in the shelf list of the Trinity College Library Newton Collection, it is quite clear, as will be shown, that Newton did have a copy of this book in his possession, at least in the period of 1664-1665.

The folios concerned with colors, headed "Of Colours," in the "Quaestiones" are 105v, 122r, 122v, 123r, 123v, 124r, 124v, 133r, 133v, 134r, 134v and 135r. These constitute nearly twice as many folios as those devoted to any other single topic, and the last six of them, as well as much of the others, are drawn from Boyle's work.

Beginning on folio 122v and continuing through all the remaining above mentioned folios, Newton numbers fifty one successive entries of which I have been able to trace the last 37 with the exception of number thirty four. Since it would take a considerable number of pages for a total review, I will instead give a sampling of them including two (numbers 26 and 47) mentioned by A. R. Hall in his article "Sir Isaac Newton's Note-Book, 1661-65" and place the remaining ones in table 2 following them.

On folio 124v Newton writes the following:

> 15 Put as much common Sublimate into hot faire water as it can dissolve filter y^e solution through cap paper y^t it may be lympid. & into 2 spoone fulls of it, put about 5 drops of good limpid spirits of urine. & it will be white like milke to w^ch if you put in some rectified Aqua-fortis it will be transparent. more fresh spirits of urine will make it looke white but not so white as before.

In Boyle's <u>History of Colours</u> we find on pp. 708-9,

> Take then what quantity you please of fair water and having heated it, put into it as much good common sublimate, as it is able to dissolve, and (to be sure of having it well glutted) continue putting in the sublimate, till some of it lie untouched in the bottom of the liquor. Filter this solution through cap-paper, to have it clear and limpid, and into a spoonful or two there of

> (put into a clean glass-vessel) shake about four or five drops (according as you took more or less of this solution) of good limpid spirits of urine, and immediately the whole mixture will appear white like milk; to which mixture if you presently add a convenient proportion of rectified aqua fortis (for the number of drops is hard to determine, because of the differing strength of the liquor, but easily found by trial) the whiteness will presently disappear, and the whole mixture become transparent; which you may, if you please, again reduce to a good degree of whiteness (though inferior to the first) only by a more copious affusion of fresh spirits of urine.[14]

On folio 133r Newton writes,

> 19 Gold & silver melted into a lumpe & dissolved by Aqua fortis y^e^ powder of gold falling to y^e^ bottome appears not yellow but black though neither y^e^ gold silver nor Aqua fortis be so, & silver rubbed on other bodys colours y^m^ black.

While on pages 713-4 of Boyle's History of Colours we find,

> When we dissolve in aqua fortis a mixture of gold and silver melted into one lump, it usually happens, that the powder of gold, that falls to the bottom, as not being dissoluble by that menstruum, will not have its own yellow, but appear of a black colour, though neither the gold, nor the silver, nor the aqua fortis did before manifest any blackness. . . . I have divers times observed in wearing silver-hilted swords . . . that where they rubbed upon my clothes, if they were of a light-coloured cloth, the affriction would quickly black them . . .[15]

On folio 133v of the "Quaestiones" we find the following entry:

> 26. A feather or black ribband put twixt my eye & y^e^ setting sunne makes glorious colours.

Which is a paraphrase of Boyle's comments on page 743.

> I took then a feather of a convenient bigness and shape, and holding it at a fit distance betwixt my eye and the sun when he was near the horizon, me thought there appeared to me a variety of little rainbows, with differing and very vivid colours, of which none was constantly to be seen in the feather; the like phenomenon I have at other times (though not with altogether so good success)

> produced, by interposing at a due distance a piece of black ribbaned betwixt the almost setting sun and my eye; not to mention the trials I have made to the same purpose, with other bodies.[16]

And as a last example, entry 47, to be found on folio 134v of the "Quaestiones."

> 47 take Lignum Nephriticum (y^e^ infusion of w^ch^ in faire water is good against y^e^ stone of y^e^ kidneys) put a handfull of thin slices of it into 3 or 4 pound of pure spring water after it hath infused there a night put y^e^ water into a cleare viall, & if you see the light through it it appears of a golden colour (excepting sometimes a sky coloured circle at y^e^ top) but if y^e^ infusion was too strong y^e^ liquor will then appeare darke & reddish. But if your eye is twixt y^e^ liquor & light it appears ceruleous: etc. Acid salts destroy y^e^ blew-colour & sulphureous saltes restore it againe w^th^out making any change in y^e^ golden colour, Which may bee usefull to y^e^ finding whither bodys abound more with acid or sulphureous Salts.

That this too comes from Boyle's work is made evident if we compare it with the following:

> Take Lignum Nephriticum, and with a knife cut it into thin slices; put about a handful of these slices into two, three or four pounds of the purest spring-water; let them infuse there a night. . . . Decant this impregnated water into a clear glass phial; and if you hold it directly between the light and your eye, you shall see it wholly tincted, (excepting the very top of theliquor, wherein you will sometimes discern a sky-coloured circle) with an almost golden colour, unless your infusion have been made too strong of the wood; for in that case it will against the light appear somewhat dark and reddish . . . But if you hold this phial from the light, so that your eye be placed betwixt the window and the phial, the liquor will appear of a deep and lovely ceruleous colour . . . I imagined that the acid salts of the vinegar having been able to deprive the liquor of its ceruleous colour, a sulphureous salt being of a contrary nature, would be able to mortify the saline particles of vinegar, and destroy their effects . . .[17]

A. R. Hall attributes both 26 and 47 above from Newton's "Quaestiones" to Newton himself, seeing them as a part of the story of Newton's development in optics which led to his theory of colors in the winter of 1666. That they are a part of the development is certain, but they were Boyle's contribution to that development and not Newton's.[18]

TABLE 2

THE SOURCES OF ENTRIES 15-51 OF NEWTON'S "QUAESTIONES" IN BOYLE'S HISTORY OF COLOURS

"QUAESTIONES"		HISTORY OF COLOURS
FOLIO(S)	ENTRY	PAGE(S)
124v	15	708-9
124v	16	709
133r	17	710-11
133r	18	712
133r	19	713-4
133r	20	719
133r	21	721
133r	22	722-3
133r	23	728
133r	24	741-2
133r	25	739
133v	26	743
133v	27	743-4
133v	28	745
133v	29	746
133v	30	747
133v	31	753

TABLE 2-Continued.

"QUAESTIONES"		HISTORY OF COLOURS
FOLIO(S)	ENTRY	PAGE(S)
133v	32	761-2
134r	32*	769-70
134r	33	?
134r	34	762
134r	35	786
134r	36	701
134r	37	720
134r	38	709
134r	39	729
134r	40	751
134r	41	753
134r	42	784
134r	43	785
134r	44	786
134r&v	45	787
134v	46	769
134v	47	729-31,733-4
134v	48	**
134v&135r	49	**
135r	50	**
135r	51	734-5

*There are two entries numbered "32."

**Apparently comments and conclusions on previous entries with some cross references.

Having established that during the period 1661-1665 Newton read Boyle's Spring of the Air, History of Cold and History of Colours, we can now turn to a consideration of the epistemological and methodological content of these works and their possible influence on Newton's thought in that period.

The Influence of Boyle

Perhaps the most interesting thing that Newton found on the epistemological side of Boyle was his treatment of causes and hypotheses.

After the description of his first experiment concerning the spring of the air, Boyle puts forward an hypothesis to explain the air's behavior. The hypothesis is that the air consists of parts which are compressed or bent by the pressures of contiguous bodies but which press back against these bodies,

> . . . yet, each of them (by virtue of its structure) is endowed with a power or principle of self-dilation . . .[19]

Boyle goes on to mention that there exists another possible explanation of the air's behavior namely that of Descartes, after the explication of which he writes,

> . . . I am not willing to declare peremptorily for either of them against the other. And indeed, though I have in another treatise endeavoured to make it probable, that the returning of elastical bodies (if I may so call them) forcibly bent, to their former position, may be mechanically explicated; yet I must confess, that to determine whether the motion of restitution in bodies proceed from this, that the parts of a body of a peculiar structure are put into motion by the bending of the spring, or from the endeavour of some subtle ambient body, whose passage may be opposed or obstructed, or

> else its pressure unequally resisted by reason of the new shape or magnitude, which the bending of a spring may give the pores of it: to determine this, I say, seems to me a matter of more difficulty, than at first sight one would easily imagine it. Wherefore I shall decline meddling with a subject, which is much more hard to be explicated than necessary to be so by him, whose business it is not, in this letter, to assign the adequate cause of the spring of the air, but only to manifest, that the air hath a spring, and to relate some of its effects.[20]

The behavior of the air is to be explained therefore by reference to a power of the corpuscles or parts of the air. These powers are, however, themselves the product of the structure of those corpuscles and are, at least in principle, explainable by it. Yet that explanation in terms of structure is too difficult to carry out "here" and is therefore omitted. Its omission is in this case, as in all others, qualified by the claim that it is unnecessary for the task at hand which is merely to note the existence and consequences of the power. All of this is very curious indeed, for we have merely reduced the power of a body to the power of its parts and the powers in both cases are the same, viz., that of a spring. Now, the air does not look like a spring but the corpuscles have no look at all and so may be structurally spring-like. In fact Boyle writes as if they actually came equipped with little springs.

> So that, according to a moderate estimate of the thickness of the atmosphere, we may well suppose, that a column of air, of many miles in height, leaning upon some springy corpuscles of air here below, may have weight enough to bend their little springs, and keep them bent . . .[21]

That Boyle did not mean this merely as an analogy can be seen from the continuation of the quotation above.

> . . . as, (to resume our former comparison,) if there were fleeces of wool piled up to a mountainous height one upon another, the hairs, that compose the lower most locks, which support the rest, would, by the weight of all the wool above them, be as well strongly compressed, as if a man should squeeze them together in his hands, or employ any such other moderate force to compress them.[22]

<u>This</u> is the analogy which here is offered in support of what must be taken as the reality, for one doesn't support one analogy with another.

But we are being unfair to Boyle, for he apparently believed that those springy corpuscles that made up the air were themselves made up of other corpuscles and these were not springy in themselves but by coming together in certain structures produced those longer springy bodies.

> . . . we shall . . . add this . . . that if, as <u>Leucippus</u>, <u>Democritus</u>, <u>Epicurus</u> and others, followed by divers modern Naturalists, have taught, that the difference of bodies proceeds but from the various magnitudes, figures, motions and textures of the small parts they consist of, (all the qualities that make them differ, being deducible from thence) there appears no reason why the minute parts of water, and other bodies, may not be so agitated or connected as to deserve the name of air. . . . And if we will have the air to be a congeries of little slender springs, it seems not impossible, though it be difficult, that the small parts of divers bodies may by a lucky concourse of causes be so connected, as to constitute such little springs . . .[23]

If Boyle had only gone from the springiness of the air to the springiness of its parts and stopped there, as indeed he appears to do on page 14 of <u>The Spring of the Air</u>, and not indicated that they in turn are made up of non-springy corpuscles, as he does on page 54, he would have explained nothing.

It is common practice in the sciences to explain a dispositional property by reducing the objects having that property to a set of smaller objects standing in a set of structural relations. These smaller objects in their turn are described (if not immediately, then eventually) in terms of dispositional properties. But these dispositional properties are invariably different from the ones which we begin by explaining; if they were not we would not, and should not, feel that we had made any advance on our previous knowledge.

To the mature Newton any explanation of the spring of the air by the postulation of a property of springiness, either as a property of the air or of the corpuscles of which it is constituted, would, as we will see more clearly in the next chapter, seem a recourse to occult qualities and thus unacceptable. Which is not to say that Boyle would have thought occult qualities acceptable. Boyle was perhaps the most effective of those who arguedagainst their use.

Although Boyle's principal attacks on occult qualities do not appear in the works which we are considering, the following passage does occur in <u>The Spring of the Air</u>:

> And the reason why there cannot be a void, being by them taken, not from any experiments, or phenomena of nature, that clearly and particularly prove their hypothesis, but from their notion of a body, whose nature, according to them, consisting only in extension . . .

> to say a space devoid of body, is, to speak in the schoolmen's phrase, a contradiction *in adjecto*. This reason, I say, being thus desumed, seems to make the controversy about a vacuum rather a metaphysical, than a physiological question; which therefore we shall here no longer debate, finding it very difficult either to satisfy Naturalists with this Cartesian notion of a body, or to manifest wherein it is erroneous, and substitute a better in its stead.[24]

Those hypotheses which are acceptable within natural philosophy are then only those which are clearly and particularly proven by experiments or the phenomena of nature. More interestingly Boyle has here labeled hypotheses that are not thus clearly and particularly proven, "metaphysical."

The general attitude of Boyle toward hypotheses or theories is reflected in the very titles of two of our three works, *A History of Cold Begun* and *A History of Colours Begun*. The notion of a history as used in these titles derives from Francis Bacon's conception of scientific method which plays a major role in the way in which Boyle conceives of his enterprise.

> . . . I must desire, that you would look upon this little treatise, not as a discourse written principally to maintain any of the fore-mentioned theories, exclusively to all others, or substitute a new one of my own; but as the beginning of a history of colours, upon which when you and your ingenious friends shall have enriched it, a solid theory may be safely built.[25]

But Boyle is not quite so naive as Bacon in his conception of science, for he goes on,

> But yet because this history is not meant barely for a register of the things recorded in it, but for an apparatus to a sound and comprehensive hypothesis, I thought fit so to temper the whole discourse, as to make it as conducible as conveniently I can to that end:

> and therefore I have not scrupled to let you see, that I was willing to save you the labour of cultivating some theories, that I thought would never enable you to reach the ends you aim at, so to contract your enquiries into a narrow compass.[26]

Despite his frequent disclaimers and warnings, Boyle always sets sail with an hypothesis under his hat--a fact that Newton couldn't have missed but must have ignored. It was Boyle's warnings like the following one from The Spring of the Air that influenced Newton.

> So apt are we to be misled, even by experiments themselves, into mistakes, when either we consider not that most effects may proceed from various causes, or mind only those circumstances of our experiment, which seem to comply with our preconceived hypothesis or conjectures.[27]

In the History of Cold Newton read,

> I presume it will easily be taken notice of, that in the following history I have declined the asserting of any particular hypothesis, concerning the adequate cause of cold. Not but that I may have long had conjectures about that matter, as well as other men, but I was willing to reserve to myself an intire liberty of declaring what opinion I most inclined to, till the historical part being finished, I may have the better opportunity to survey and compare the phenomena; and the leisure, (which I cannot promise myself in hast) of calmly considering what theory may best agree with them. . . . And whatever applause is wont in this age to attend a forwardness to assert hypotheses, yet, though fame were less to be sought than truth, this will not much move me, whilst I observe, that hypotheses hastily pitched upon do seldom keep their reputation long; and divers of them, that are highly applauded at the first, come, after a while, to be forsaken even by those that devise them.[28]

And with the raising of the problem of our preconceived hypotheses there also rises, once again, the specter of manifest experience.

Newton could not have helped but notice that Boyle, like himself, had read Galileo's Dialogue on the Great World

Systems for Boyle includes as a part of the History of Cold a dialogue clearly modeled upon it. Of particular interest to us is the fact that Boyle's dialogue stresses the problem of manifest experience in the same way that we have argued in chapter IV that Galileo's did.

The dialogue section of the History of Cold is titled "An Examen of Antiperistasis as it wont to be Taught and Proved." There are three interlocutors: Themistius, the upholder of antiperistasis and spokesman for the schools; Carneades, the natural philosopher of the modern school who, though not rejecting antiperistasis shows there are no arguments that prove its truth; and Eleutherius, a quick-witted philosopher, who neutrally listens to both sides and is convinced by Carneades. In short, Themistius is Simplicio, Carneades is Salviati and Eleutherius is Sagredo.

Themistius begins by affirming antiperistasis on the basis of manifest sense experience.

> Them. As for Antiperistasis, the truth of it is a thing so conspicuous, and so generally acknowledged, that I cannot imagine what should make some men deny it, except it be, that they find all others to confess it. For though in other cases they are wont to pretend experience for their quitting the received opinions, yet here they quit experience it self for singularity, and chuse rather to depart from the testimony of their senses, than not to depart from the generality of men.[29]

And continuing a page later, he writes,

> And as if nature designed men should not be able to contradict the doctrine of Antiperistasis, without contradicting more than one of their own senses, she has taken care, that often times the water, that is

> freshly drawn out of the deeper sorts of wells and springs, should manifestly, as I have seen it, smoke, as if it had been but lately taken off the fire. And this may be said, without a metaphor, to demonstrate _ad oculum_ the reality of Antiperistasis . . .[30]

The notions of ocular demonstration and manifest experience are clearly as much at stake here as antiperistasis. And here, as in Galileo's _Dialogue_, the attack is not on the visual "facts" but on their interpretation. Carneades does not deny that the phenomena described by Themistius occur but shows that they can be explained without reference to antiperistasis. What is more interesting is that at every turn the phenomena are shown to be dependent on our bodily state--the same water feeling hot to the cold hand and cold to the hot hand.

In Boyle's postscript to the dialogue, which is titled, "A Sceptical Consideration of the heat of Cellars in winter, and their coldness in Summer," he writes,

> The foregoing discourses of _Carneades_ seem to have sufficiently shaken the foundations of the vulgar doctrine of Antiperistasis, so far forth as it is superstructed upon the vulgar observations and phenomena, whereon men are wont to build it . . . for as to the obvious phenomena, that nature does, as it were, of her own accord present us, they seem to have been perfunctorily considered, and our senses only being the judges of them, we may easily, as _Carneades_ argues, be imposed upon by the unheaded predispositions of our organs.[31]

And if Newton himself was unable to see how these arguments against ocular demonstration and manifest experience led to (or presupposed) the primary-secondary quality distinction, Boyle pointed the way. On page 482 of the _History of_

Cold, he writes,

> For being apt to take it for granted, that our temper is the same, when there is no manifest cause, why it should be changed, we often impute that to objects, where of the cause is in our selves; and if this change in our selves be wrought by unsuspected agents, or by insensible degrees, we do not easily take notice of it.[32]

Boyle's views on the primary-secondary quality distinction are not totally revealed in the three works we are considering. What is surely his most important work on the topic, The Origin of Forms and Qualities, was not published until 1666, and, so far as I can determine, was not read by Newton prior to the completion of "De gravitatione" which, I shall argue in the next chapter, would place it outside the period during which Newton was concerned with epistemological issues. There was, however, quite enough in the History of Colours to help him form his own views.

We have already established the importance of the History of Colours to the development of Newton's thought concerning optics. We will now show that its importance to his epistemological views was of the same order. In chapter III we mentioned Newton's view that both an external object (the sun) and a mental event (his imagining the sun) could produce the same motions in his brain and thus the same sensations (an after image of the sun). Both this experiment and the thought leading up to it were suggested either wholly or in part by Boyle's History of Colours.

Boyle makes the following distinction:

> But, before we descend to the more particular considerations we are to present you concerning colours, I presume it will be seasonable to propose at the very entrance a distinction; the ignorance or neglect of which, seems to me to have frequently enough occasioned either mistakes or confusion in the writings of divers modern philosophers. For colour may be considered, either as it is a quality residing in the body that is said to be coloured, or to modify the light after such or such a manner; or else as the light itself, which so modified, strikes upon the organ of sight, and so causes that sensation which we call colour; and that this latter may be looked upon as the more proper, though not the usual acceptation of the word colour, will be made probable by divers passages in the ensuing part of our discourse.[33]

Although Newton and Boyle were to differ on whether the rays of light were the things that were colored (Newton, in the <u>Opticks</u>, saying that red light was not red but red-making),[34] they were in agreement from the outset on the need for separating the quality from the external object. In addition both of them shared the same views on the physiology of perception--that which we have seen in Henry More's <u>Immortality of the Soule</u>. These two views taken together lead to serious epistemological problems. Boyle after making the statement quoted above, writes,

> I know not whether I may not on this occasion add, that colour is so far from being an inherent quality of the object in the sense that is wont to be declared by the schools, or even in the sense of some modern Atomists, that, if we consider the matter more attentively, we shall see cause to suspect, if not conclude, that though light do more immediately affect the organ of sight, than do the bodies that send it thither, yet light itself produces the sensation of colour, but as it produces such a determinate kind of local motion in some part of the brain; which, though it happen most commonly from the motion whereinto the slender string of the retina are put, by the appulse of light; yet if the like motion happen to be produced by any other cause, wherein the

> light concurs not at all, a man shall think he sees the same colour.[35]

Boyle, not content with the mere possibility of other causes, goes on to give various examples. Amongst which are, (1) " . . . when a man receives a great stroke upon his eye, or a very great one upon some other part of his head, he is wont to see, as it were, flashes of lightening, and little vivid, but vanishing flames . . . .,"[36] (2) " . . . upon coughing strongly, it would seem to me, that I saw very vivid, but immediately disappearing flames . . . ,"[37] (3),

> . . . after I have through a telescope looked upon the sun, though thorough a thick, red, or blue glass, . . . the impression upon the retina would be not only so vivid, but so permanent, that if afterwards I turned my eye towards a flame, it would appear to me of a colour very differing from its usual one.[38]

and, finally, (4),

> . . . a person . . . told me . . . that having upon a time looked too fixedly upon the sun, thorough a telescope, without any coloured glass, to take off from the dazzling splendor of the object, the excess of light did so strongly affect his eye, that ever since, when he turns it towards a window, or any white object, he fancies he seeth a globe of light, of about the bigness the sun then appeared of to him, to pass before his eyes . . .[39]

Neither case (3) nor (4) are the ones that Newton puts forward in the "Quaestiones" but they are similar enough, particularly in context, to suggest that Newton was led to make his after-image experiments by what he read in the <u>History of Colours</u>.

Boyle does not add the problem occasioned by the fact that specific motions in our brain can have various causes to his long list of obstacles standing in the path of science. It is hard to believe, however, that Newton would not have seen it as such, given his account of the after_image experiment and Glanvill's story of the gypsy scholar.

Boyle, however, is generally optimistic about the ability of science to discover truth. This optimism seems grounded in his belief in the ability of experiment to overcome the mistakes of mere observation. The material quoted from Boyle above makes a distinction between the value of experiment as against mere observation. He qualifies observation with the term "vulgar" which is not meant to tell us how the observation is carried out but rather to point to the fact that they are by nature uncontrolled. Experiments through their controlled nature will somehow free us from the errors of "manifest experience." Boyle is not, of course, telling us to shun mere observation when nothing else is possible, but rather to use experiment wherever that is possible. The problems of perception to which Boyle draws our attention are not then meant to dissuade us from the enterprise of science; on the contrary, they are meant to point the way. What is called for is not mere observation but wary experiment. In short, scepticism regarding our sense experience once again becomes a method. At the end of a section in the History of Cold concerned with raising objections to the notion of a Primum Frigidum, Boyle writes, " . . . I think it not amiss to take notice once more, that my design in playing the sceptick on this subject, is not so much to reject other men's probable opinions of a Primum Frigidum, as absolutely false, as it is to give an account, why I look upon them, as doubtful."[40]

Thus, in conclusion, it is clear that Boyle influenced Newton in several specific ways. Most importantly he set Newton to thinking about colors in terms of experiments that he might perform. Boyle also must have reinforced Newton's view on "manifest experience" and "ocular demonstration," especially when taken in conjunction with what Newton had read in Galileo's Dialogue. In addition Boyle's use of hypotheses and disclaimers regarding them must have set Newton to thinking about the methodological problem of hypotheses in general. And finally, Newton must have been confirmed in his corpuscularianism after seeing its enormous success in the hands of Boyle in explaining a wide variety of phenomena.

NOTES

CHAPTER VIII

[1]A consideration of which editions of these works were used by Newton will follow below, but for ease of reference all quotations and page references will be from Robert Boyle, The Works of the Honourable Robert Boyle, ed. Thomas Birch (London, 1772).

[2]A. R. Hall, "Sir Isaac Newton's Note-book, 1661-65," Cambridge Historical Journal, vol. IX, 1948, pp. 239-50.

[3]The Correspondence of Isaac Newton, vol. I, p. 305; Item 120 Oldenburg to Newton september 14, 1673. Newton's copy of Experiments, Notes, etc. about the Mechanical Origine or Production of divers particular Qualities by Robert Boyle (London, 1675), Newton Collection of Trinity College Library, Cambridge, shelf mark NQ. 16. 199, was also a presentation copy. It is inscribed, "For Mr isaac Newton from the Author."

[4]Ibid., vol. II, p. 288; Item 233 Newton to Boyle February 28, 1678/9.

[5]Ibid., vol. II, p. 481; Item 309 Halley to Newton July 5, 1687.

[6]The six explicit references are on folios 90v, 96v,

97v, 99r and 106r.

[7]Boyle Works, vol. I, p. 25.

[8]Ibid., vol. I, p. 63.

[9]"Dog-earing" refers to a method, used by Newton, of indicating important passages by folding down a corner of a page so that it touched the passage wanted.

[10]I have added the numbers to the left of this passage for easier reference.

[11]Boyle's The Experimental History of Cold Begun is in volume II of Boyle Works.

[12]Folio 97v of the "Quaestiones" consists of seven paragraphs. Paragraph 1 has as its source pp. 529-30, paragraph 2 has p. 536, paragraph 3 has p. 532, paragraph 4 has pp. 547-8, paragraph 5 has pp. 540-1, paragraph 6 has p. 562, paragraph 7 has p. 570.

[13]Boyle Works, vol. II, p. 467.

[14]Ibid., vol. I, pp. 708-9.

[15]Ibid., vol. I, pp. 713-4.

[16]Ibid., vol. I, p. 743.

[17]Ibid., vol. I, pp. 729-31.

[18]Professor Hall prefaces his quotation of 26 on page 248, for instance, with the remark, "Newton also observed the colours produced by diffraction."

[19]Boyle Works, vol. I, p. 11.

[20]Ibid., vol. I, p. 12. [21]Ibid., vol. I, pp. 13-4.

[22]Ibid., vol. I, p. 14. [23]Ibid., vol. I, p. 54.

[24]*Ibid.*, vol. I, pp. 37-8. [25]*Ibid.*, vol. I, p. 695.

[26]*Ibid.* [27]*Ibid.*, vol. I, p. 47.

[28]*Ibid.*, vol. II, pp. 478-9.

[29] *Ibid.*, vol. II, p. 659.

[30]*Ibid.*, vol. II, pp 660-1.

[31]*Ibid.*, vol. II, p. 683.

[32]*Ibid.*, vol. II, p. 482.

[33]*Ibid.*, vol. I, p. 671.

[34]See chapter III, p. of this paper.

[35]*Boyle Works*, vol. I, p. 671. [36]*Ibid.*

[37]*Ibid.*, vol. I, p. 672. [38]*Ibid.*, vol. I, p. 673.

[39]*Ibid.*, vol. I, p. 674.

[40]*Ibid.*, vol. II, p. 598.

CHAPTER IX

NEWTON THE EPISTEMOLOGIST

Epistemology and Theology

In the previous chapters we have considered possible influences upon Newton's early epistemological thought. We have determined which books of the key figures of the period he read and we have considered what he found in them. Further, we have looked at his own thought in this period as it is reflected in two very early manuscripts, the "Quaestiones quaedem philosophicae" of 1661-1665 and "De gravitatione et aequipondio fluidorum" of 1666-1669. We have shown that the doctrines expounded in these works are not entirely consistent.

It is surprising that there is so little material directly concerned with issues of epistemology in either the published works of Newton or the six million words of his unpublished manuscripts. It has become almost a cliche to say that what little did appear in print was inconsistent with science as he practioed it. Viewing his published statements on epistemology alone and out of context Newton seems a precursor of the positivists, a shunner of metaphysical hypotheses, a "hard-nosed" scientist seeking only the truth.

If we consider his published statements on physics the picture changes, for there we find what seems a stubborn adherence to a "clearly" metaphysical doctrine of the absolute character of time and space, and an acceptance of Baconian induction with its attendant certainty of proof by experiment.

It would be nice to resolve these inconsistencies in a new interpretation of the Newtonian corpus and have all the pieces neatly fall into place in a newly apprehended consistent whole, but I don't think that this is entirely possible. What we must do is look for the source of the inconsistency and try to understand it. We have seen that there were inconsistencies in Newton's views from their beginnings in his student years at Trinity College, Cambridge. What we will do in this final chapter is look at those inconsistencies again and consider whether they are the same inconsistencies that are to be found in his mature writings and whether they spring from the same sources.

I have maintained in chapter II that the materialism of Hobbes was extremely attractive to the young Newton, that he did not attack it, though he did object to various specific doctrines it contained. What he found appealing in it was its orderliness and its sense of having found a clear path to success. The problem of how to proceed in science seemed solved in materialism. The mind's contribution to perception seemed, at least in principle, determinable. The mind was, after all, the brain; and the brain and its operation could be studied. Once we understood the mechanical interactions of brain and body we could make the appropriate "defalkations" and determine which qualities were really primary and applying this to our investigations of how bodies interact we would arrive at a true and certain picture of the world. That Newton saw this as a kind of ideal is clear from folio 101v of the "Quaestiones" which we have quoted on page 23. There was only one difficulty with materialism, and that was that it was false. That it couldn't be true was clear to Newton from his reading of the bible--spirit existed in the world whatever this fact's inconvenience for physics.

There appeared then, two possible ways of dealing with the problem of perception envisaged as the problem of knowing which perceived qualities were genuinely of the object and which arose merely from the interactions of our minds and bodies with the object--the problem of distinguishing the real qualities from the pseudo qualities. One was to ignore the problem by adopting a form of the primary-secondary quality distinction _a priori_ and thus to ignore the issue of how objects interact with the mind; the other was to follow the same program as the materialists--to first determine how mind and body acted upon each other and then return to the problems of the nature of bodies. Such a procedure necessitated a monism, as the difficulties of interaction had shown, and, since materialism was false, idealism was the natural alternative. We have seen that Newton inconsistently adopted both ways of dealing with the problem. The first is reflected in his shunning of hypotheses, in the unimportance accorded causes. The second is more obviously stated in his attempt to reduce the problems of the behavior of physical bodies to the problem of how the will directs and causes the motions of the body, and in his account of physical bodies as impenetrable regions of space endowed by God with the power to cause sensations in created minds. It is clear that within this account the principal concern would be with causes and origins.

The problem was that whereas Newton knew how a materialist would proceed to make the necessary investigations into perceptual situations, he did not know how an idealist should proceed. Introspection into the operations of the will helped very little, and no other methodology presented itself; except perhaps that theological considerations might help. The operations of God's will were, according to Newton, more closely related to the operations of man's will and thus to the nature of physical bodies than one would ordinarily believe. As we have seen Newton state it,

> Thus I have deduced a description of this corporeal nature from our faculty of moving our bodies, so that all the difficulties of the conception may be at length reduced to that; and further, so that God may appear (to our innermost consciousness) to have created the world soley by an act of will alone; and, besides, so that I might show that the analogy between the Divine faculties and our own is greater than has formerly been perceived by Philosophers.[1]

Thus theological investigation might shed light on the nature of physcial bodies.

Much has been made of the fact that Newton spent a great deal of his time in non-scientific pursuits such as alchemy, chronology and theology. R. J. Forbes in his article, "Was Newton an Alchemist?"[2] presented a comparison based upon the numbers of volumes in Newton's library on varied subjects as compiled from the Huggins'-Musgrave List purporting to show where Newton's interests lay. The comparison is as follows:

Theology and philosophy	515 titles	32%
History and chronology	215	14
Classical Authors	182	11
Chemistry, minerology, and alchemy	165	10
Mathematics, physics and astronomy	268	16
Geography	76	5
Philology, grammars, and miscel.	95	6
Medicine, biology, and husbandry	52	3
Coinage, numismatics	35	2
Technology	18	1

It would be foolish to conclude from this list that Newton was twice as interested in philosophy and theology as in mathematics, physics and astronomy. On the other hand it would be a mistake to account for the number of these volumes by an appeal to the proverbial long-windedness of philosophers and theologians. We can conclude, however, that Newton was profoundly concerned with theological matters.

The majority of Newton's theological manuscripts, now known as the Yahuda manuscripts after the orientalist and collector A. S. Yahuda, are to be found in the Jewish National and University Library in Jerusalem. They reveal a life-long concern with theological issues and a consistently held view as to the nature of God.

At the heart of Newton's religion was the notion of an active God, one who exerted dominion over His creation and whose will was the primary active force in the world. God's omniscience, omnipotence and beneficence, i.e., his necessary essential properties, were to be worshipped, but what was most to be celebrated were His actions.

Although this doctrine was first publicly expressed by Newton in the General Scholium of the second edition of the *Principia* in 1713 as a partial answer to the criticisms of Leibniz (and unnamed others), it would be a mistake to think that this theological position was merely constructed to meet those objections. In fact this doctrine is to be found throughout Newton's theological writings and lies behind the position taken in "De gravitatione."

Frank E. Manuel in his book, *The Religion of Isaac Newton*, has gathered together many of the most explicit statements of Newton's doctrine, drawn principally from the Yahuda manuscripts, two of which will suffice to make Newton's position clear,

> If God be called ὁ παντοκράτωρ the omnipotent, they take it in a metaphysical sense for Gods power of creating all things out of nothing whereas it is meant principally of his universal irrestible monarchical power to teach us obedience. For in the Creed after the words I believe in one God the father almighty are added the words creator of heaven and earth as not included in the former. If the father or son be called God, they take the name in a metaphysical sense as if it signified Gods metaphysical perfections of infinite eternal omniscienct omnipotent whereas it relates only to Gods dominion to teach us obedience. The word God is relative and signifies the same thing with Lord and King, but in a higher degree. As we say my Lord, our Lord, your Lord, the King of Kings, and Lord of Lords, the supreme Lord, the Lord of the earth, the servants of the Lord, serve other Lords, so we say my God, our God, your God, the God of Gods, the supreme God, the God of the earth, the servants of God, serve other Gods: but we do not say my infinite, our infinite, your infinite, the infinite of infinites, the infinite of the earth, the servants of the infinite, serve other infinites. When the Apostle told the Gentiles that the Gods which they worshipped were not Gods, he did not mean that they were not infinites, (for the Gentiles did not take them to be such:) but he meant they had no power and dominion over man. They were fals Gods; not fals infinites, but vanities falsly supposed to have power and dominion over man.[3]

And,

> To celebrate God for his eternity, immensity, omnisciency, and omnipotence is indeed very pious and the duty of every creature to do it according to capacity, but yet this part of God's glory as it almost transcends the comprehension of man so it springs not from the freedom of God's will but the necessity of his nature . . . the wisest of beings required of us to be celebrated not so much for his essence as for his actions, the creating preserving, and governing of all things according to his good will and pleasure. The wisdom, power, goodness, and justice which he always exerts in his actions are his glory which he stands so much upon, and is so jealous of . . . even to the least tittle.[4]

We have already stated that Newton accepted the Morean notion of extended spirit and the concomitant Hobbesian claim that to exist is to be spatially located, i.e., to be in space. In "De gravitatione" these doctrines are put forward as part of the Newtonian theory of space. On page 136 of "De gravitatione" Newton writes, " . . . whatever is neither everywhere nor anywhere does not exist. And hence it follows that space is an effect arising from the first existence of being, because when any being is postulated, space is postulated." And further on he states, "Lastly, space is eternal in duration and immutable in nature, and this because it is the emanent effect of an eternal and immutable being."[5] Space then is an effect of God's existence owing its properties to the kind of existent being He is. Its creation is not, however, the product of an act of will, it is merely a concomitant of His existence. Material bodies, on the other hand, are products of God's will. As products of His will, their nature is in no way deducible from His nature. We must come to know material objects through sensations alone. Since we too are products of God's will our own natures are also to be known through sensation. Since sensation is dependent on the natures of material objects and ourselves, we are left once again with what appears to be the insuperable problem of perception.

Thus no consideration of God's nature could lend us insight into the nature of physical bodies. There is however, another possibility--we might come to know the nature of the acts of God's will through His word, i.e., through revelation and prophecy.

Newton was thoroughly convinced that man was capable of correctly interpreting scripture and that he was himself capable of doing so. But scripture, unfortunately, did not contain information as to the nature of perception. This is not to say that God did not give knowledge of this sort to man, for apparently Newton believed that God had given a knowledge of all things to Moses. This position was viewed by Newton as at one with the view that the ancient world had had the knowledge which we now seek. Newton, who gave little credit to his contemporaries, was willing to credit the ancient world with all his discoveries.[6]

In the final analysis, then, Newton's theology doesn't answer his questions regarding the nature of perception, but the active nature of God makes plausible the view expounded in the "De gravitatione" regarding the nature of bodies. Everywhere God wishes to manifest his activity and thus in all his acts of will He creates entities which are essentially active, such as the minds of men and physical bodies. Only those products of God which, like space, are concomitant effects of his essential being, rather than products of his will, are passive.

Since Newton was never able to carry out his theological program and could not therefore establish with certainty which were the real and which the pseudo qualities, he turned more and more to the possibility of deciding which qualities should be regarded as the primary qualities on pragmatic grounds. He seemed more and more to be saying, treat those qualities as primary, i.e., real, which figure in our successful explanations of phenomena.

Rule III of the Rules of Reasoning which appear in the Principia states, "The qualities of bodies, which admit neither intensification nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever."[7] Although this rule makes it appear as if the identification of real qualities is a purely empirical matter, we have argued at length in chapter VI that it is not. What we are being given in Rule III is a methodological rule, a rule to be prefaced with the phrase, "act as if." The Rules of Reasoning are, as I. Bernard Cohen describes them, general procedural precepts for science.[8]

The fact that Rule III was added to the second edition of the Principia in 1713 is a further indication that Newton's epistemological views had not changed from those of the period of the "Quaestiones" and "De gravitatione" forty six years earlier.

The situation was, then, that Newton had sought an account of the nature of bodies and perception that would have allowed him to determine which of the qualities we perceive were actually in the external bodies that caused our sensations or, if the matter were more complicated, to determine from the qualities we did perceive what qualities were in the object, even if none of those real qualities were perceived. On theological and epistemological grounds he constructed the theory of "De gravitatione" which reduces the problem of how objects produce sensations in us to the problem of how our minds move our bodies. The theory as stated in "De gravitatione" contains a list of primary qualities: extension, mobility and impenetrability according to certain laws; but how these qualities cause our sensations and thus how we can establish that they are the primary qualities through our experience is left to wait upon the solution of the problem of how the mind moves the body. Since the answer to this last question was not forthcoming, Newton continued to hold to the list of primary qualities in "De gravitatione" but attempted to justify their acceptance as the primary qualities pragmatically--it was useful to so consider them. We must keep in mind, however, that Newton was nonetheless convinced that they were primary qualities though I think he was not certain that there were not others, attraction, for instance.

When later he was forced by his critics to consider the possibility that gravitation, i.e., attraction, was a primary quality he found that he needed more than pragmatic grounds for making the decision. I believe it is obvious, despite Newton's protestations, that gravity would qualify as a primary quality under Rule III of the Rules of Reasoning of the *Principia*. But that was not sufficient for Newton, for to classify it so would smack too much of the schools' explanations by occult qualities, or at least it might seem so to others. Newton's notion of active body made the idea that bodies might have the power of drawing other bodies toward themselves not implausible, but Newton needed the certainty that only his theological program could have provided to back a decision that might have been met with derision by his respected contemporaries. So instead he turned back to hide behind the wall of "Hypotheses non fingo," a dictum which if consistently applied would have left him unable to designate any qualities as really "in" objects.

If Newton's sole reason for his theological research was his attempt to discover the real nature of mind and body he would have dropped his theological conclusions in favor of the scepticism dictated by his views on perception, but the matter was otherwise. Newton's theological position in his view was capable of standing on its own on the basis of scriptural evidence and he was willing to commit some of these views to the printed page. They are to be found in the *Principia*[9] and in the Querys to the *Opticks*[10] but perhaps most interestingly, in relation to the position of "De gravitatione," in Clarke's First Reply of the *Leibniz-Clarke Correspondence*. Clarke expresses a view that we can now clearly recognize as Newton's.

> The notion of the world's being a great machine, going on without the interposition of God, as a clock continues to go without the assistance of a clockmaker; is the notion of materialism and fate, and tends, (under pretence of making God a *supra-mundane intelligence*,) to exclude

> providence and God's government in reality out of the world. And by the same reason that a philosopher can represent all things going on from the beginning of the creation, without any government or interposition of providence; a sceptic will easily argue still farther backwards, and suppose that things have from eternity gone on (as they now do) without any true creation or original author at all, but only what such arguers call all-wise and eternal nature. If a king had a kingdom, wherein all things would continually go on without his government or interposition, or without his attending to and ordering what is done therein; it would be to him, merely a nominal kingdom; nor would he in reality deserve at all the title of king or governor. And as those men, who pretend that in an earthly government things may go on perfectly well without the king himself ordering or disposing of any thing, may reasonably be suspected that they would like very well to set the king aside: so whosoever contends, that the course of the world can go on without the continual direction of God, the Supreme Governor; his doctrine does in effect tend to exclude God out of the world.[11]

That Newton never gave up the essential features of the theological program is also made clear by their inclusion in the last paragraph of the General Scholium of the <u>Principia</u> which appeared for the first time in the second edition (1713). There he writes,

> And now we might add something concerning a certain most subtle spirit which pervades and lies hid in all gross bodies; by the force and action of which spirit the particles of bodies attract one another at near distances, and cohere, if contiguous; and electric bodies operate to greater distances, as well repelling as attracting the neighboring corpuscles; and light is emitted, reflected, refracted, inflected, and heats bodies; and all sensation is excited, and the members of animal bodies move at the command of the will, namely, by the vibrations of this spirit, mutually propagated along the solid filaments of the nerves, from the outward organs of sense to the brain, and from the brain into the muscles. But these are things that cannot be explained in few words, nor are we furnished with that sufficiency of experiments which is required to an accurate determination and demonstration of the laws by which this electric and elastic spirit operates.[12]

Here, as in "De gravitatione," various problems regarding the powers of bodies are reduced to the problem of how our will moves our bodies. What is perhaps most interesting in this case is that the "power" chiefly referred to in this passage is that of attraction. In light of "De gravitatione" this would seem to put attraction amongst the primary qualities but then, just as in "De gravitatione," to consider a mechanical explanation of the way in which the power is manifested. Thus all the problems of Newton's inconsistent theories of perception and matter persist in his views to the end.

As still further evidence of the persistence of the views we have found in the "Quaestiones" and "De gravitatione" I will include the following further passage from the General Scholium:

> We have ideas of his [God's] attributes, but what the real substance of anything is we know not. In bodies, we see only their figures and colors, we hear only the sounds, we touch only their outward surfaces, we smell only the smells, and taste the savors; but their inward substances are not to be known either by our senses, or by any reflex act of our minds: much less, then, have we any idea of the substance of God. We know him only by his most wise and excellent contrivances of things, and final causes; we admire him for his perfections; but we reverence and adore him on account of his dominion: for we adore him as his servants; and a god without dominion, providence, and final causes, is nothing else but Fate and Nature.[13]

The most interesting piece of evidence for the persistence of Newton's early views involves a passage in Locke's <u>Essay Concerning Human Understanding</u>. In Book IV, chapter x, section 18, Locke writes a very unclear passage about the possible creation of matter out of nothing. Pierre Coste, who translated the Essay into French and also translated Newton's Opticks (Amsterdam, 1720), added the following footnote to the Locke passage just mentioned:

> Here Mr. Locke excites our curiosity, without being inclined to satisfy it. Many persons, imagining that he must have communicated to me this mode of explaining the creation of matter, requested, when my translation first appeared, that I would inform them what it was; but I was obliged to confess that Mr. Locke had not made even me a partner in the secret. At length, long after his death, Sir Isaac Newton, to whom I was accidently speaking of this part of Mr. Locke's book, discovered to me the whole mystery. He told me, smiling, that he himself had suggested to Mr. Locke this way of explaining the creation of matter; and that the thought had struck him one day, when this question chanced to turn up in a conversation between himself, Mr. Locke, and the late Earl of Pembroke. He thus described to them his hypothesis: --We may (he said) have some rude idea of the creation of matter, if we suppose that God by his power had (at a certain time) prevented the entrance of anything into a certain portion of space,--space being in its own nature penetrable; for henceforward this portion of space would be endowed with impenetrability, one of the essential qualities of matter; and we have only again to suppose that God communicated the same impenetrability to another portion of space, and we should then obtain an idea of the mobility of matter, another of its essential qualities.[14]

The fact that Coste has Newton attributing the occasion of the idea to a discussion with Locke and Pembroke seems strange, knowing as we do its much earlier occurence in "De gravitatione." But given the fact that Coste couldn't have known of this early manuscript, the story of his hearing the idea from Newton rings true. Given the fact that Locke died in 1704 and we are told that this conversation with Coste took place "long after his death" and the fact that the footnote wasn't added until the third edition of 1735, we can confidently conclude that Newton continued to hold his early metaphysical views of "De gravitatione" for the remainder of his life.

Space and Qualities

In chapter V we asked whether Newton identified primary qualities as those qualities which were quantifiable and thus susceptible to mathematical treatment. It is difficult to give a very direct answer to this question. For one thing every quality is quantifiable under some operational definition or other, although some are more easily or "naturally" so than others. For another, although Newton surely did not choose them simply because they were quantifiable but because they were the qualities traditionally considered as primary <u>and</u> because they were successfully employed in scientific explanation, his notion of science would surely have led to attributing that success in large measure to their mathematical character.

In the case of space and time Newton clearly identifies that which is "mathematical" with that which is "actual," "true" or "real." In the Scholium to the "Definitions" of the <u>Principia</u>, Newton wrote,

> I do not define time, space, place, and motion, as being well known to all. Only I must observe, that the common people conceive those quantities under no other notions but from the relation they bear to sensible objects. And thence arise certain prejudices, for the removing of which it will be convenient to distinguish them into absolute and relative, true and apparent, mathematical and common.[15]

To what degree can we treat relative, apparent, common space as the space we perceive, and absolute, true, mathematical space as the space lying behind our perceptions? If the analogy is a close one it may shed some further light on the way in which Newton conceived of the relationship between the primary qualities and the secondary qualities that represented them.

Newton goes on in the Scholium to write,

> II. Absolute space, in its own nature, without relation to anything external, remains always similar and immovable. Relative space is some moveable dimension or measure of the absolute spaces; which our senses determine by its position to bodies; and which is commonly taken for immovable space; . . . Absolute and relative space are the same in figure and magnitude; but they do not remain always numerically the same.[16]

And several pages later, he writes,

> But because the parts of space cannot be seen, or distinguished from one another by our senses, therefore in their stead we use sensible measures of them. For from the positions and distances of things from any body considered as immovable, we define all places; and then with respect to such places, we estimate all motions, considering bodies as transferred from some of those places into others. And so, instead of absolute places and motions, we use relative ones; and that without any inconvenience in common affairs; but in philosophical disquisitions, we ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them. For it may be that there is no body really at rest, to which the places and motions of others may be referred.[17]

The first thing to note is that absolute space like external objects is not itself perceivable. Just as we see at most "pictures" of the external objects "projected" in our brain, we perceive only the relations amongst those objects as space, i.e., relational space. Similarly, just as our naive realism with regard to objects generally suffices for common discourse, so does our use of the notion of relational space. When we are concerned with philosophical issues, however, and here we can see that what we called an analogy is far more, Newton tells us, " . . . we ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them."

What does Newton mean when he says that absolute space may or may not be numerically the same as our relational space? If the objects we regard as at rest happen to really be at rest, i.e., with regard to absolute space, then the relational space which those objects define is numerically identical with absolute space. If, however, those objects are not really at rest then the space they define is numerically different from absolute space and is in motion with respect to it. The matter is far more complex if we take Newton's theory of perception into consideration.

Relational space, in so far as we perceive it, is the relations that exist among the "pictures" in our brains. When we consider those "pictures" to be representations of external objects we project those objects and their relations outside of ourselves. It looks to us, of course, as if they are outside to begin with. We become aware of this "projecting" only upon reflection as to the nature of perception. Now, it is clearly this external relational space that either is or is not numerically identical with absolute space. The relations that exist among the "pictures" in our brains could never be numerically identical with absolute space. The matter is yet further complicated when we consider that according to the theory of "De gravitatione" those "pictures" in our brains are caused by regions of space endowed by God with the power to produce sensations in created minds. It is clear that the regions of space that God so endows are regions of absolute space. Since regions of absolute space cannot move and objects clearly do, it must be that cases of absolute motion are cases in which different regions of space are endowed with the same powers in orderly succession. Thus to say that the objects move is to say that the powers "move." God is then busier than we thought. It is not sufficient for Him to endow a given region of space with the power to produce sensations in us, He must also, in the case of moving bodies, endow successive regions of space with that same power while withdrawing it from the previous regions. But what we are concerned with here is not the crowded nature of God's schedule but the relation between our perceptions and external objects, so let us return to that issue.

We can now ask the interesting question, Are the objects we see numerically identical to the "things themselves"? As in the case of relational space, we are not asking if the "pictures" in our brains are ever numerically identical with the things themselves, for clearly they are never so. We are asking whether the objects we see as being "out there" are numerically identical with those regions of space that have been endowed with the power to make us see objects.

There is an initial inclination to respond that the case is just like that of relational and absolute space, i.e., that they may or may not be numerically identical, because we are after all speaking of regions of space. But this would not be correct. Newton definitely gives the impression that the extension of the region of space and the "sensory extension" of our sense of sight and touch are so related that the latter informs us of the former. But when we say that the object projected into space is identical to a region of absolute space, do we mean the object with all its properties is thus identical? We identified the boundaries of that region with the visual and tactile boundaries of the object as perceived. The object as extended and as the locus of the cause of our perceptions was what we took to be identical with the region of space. In short it is just those qualities that Newton considers as primary, including his notion of powers, that we take as being so identical. The region is not red though it may be a reflector of red-making rays of light and so for all the secondary qualities, none of which are identical with the region of absolute space, but which are caused in us by the powers that reside, no matter how briefly, in a region of absolute space.

In this way we can be assured that when we see an object "out there," and we are normal observers, we are "seeing" a region of absolute space. We cannot, however, reidentify the region of absolute space we are seeing, although we can, of course, reidentify the object we are seeing.

The above is a consequence of Newton's theory of motion. If an object is in an inertial state, we can in no way tell if it is in fact moving or in a state of rest. In the case of such objects, although we can be assured that whenever we see them we are seeing a region of absolute space, we cannot be assured that we are seeing the same region through time or different regions at each instant.

If an object is in a non-inertial state then we can be assured that we are seeing a different region of absolute space each instant, but we may or may not be seeing the same region at different times. To help clarify this last remark consider an object moving non-inertially in what is apparently a circle. It would appear that every 360° the object is in the same place again, i.e. that the "powers" have been once again given to the same region of space. Despite the absolute character of non-inertial motion in the Newtonian theory, however, there may be an inertial component in the motion which is shared by the observer and which is, in principle, undetectable. Thus we can never tell if the place occupied by the object is the same place or a different place from the one occupied 360° ago.

Thus whenever I successfully see an object as out there, it is numerically identical with a region of absolute space at every instant that I see it, but the region may or may not be a different region at each instant.

A somewhat perlexing consequence of this fact should be noted. If we consider a moving object A which occupies region x at t_1 and region y at t_2, we can see that A is numerically identical with region x at t_1 and with y at t_2 but that regions x and y are at no times numerically identical. Since A is numerically identical with itself at all times we have as a consequence of the foregoing that two things (x and y) numerically identical to a third thing (A) need not be numerically identical to each other. One way round this unsatisfactory situation is to argue that regions of space are not different entities; that space has no parts; that speaking as if regions were parts is just that-- a way of speaking or conceptualizing, but that in reality all of space is a unity. In the Scholium to "Definitions" of Book I of the Principia, Newton writes,

> III. Place is a part of space which a body takes up, and is according to the space, either absolute or relative. I say, a part of space, not the situation, nor the external surface of the body.[18]

Given this definition Newton seems committed to the view that space does have parts, but they are very strange parts indeed. For one thing the parts are of various extent dependent upon the extent of the body that "takes up" the space. For another the parts cannot move in relation to each other or any other way. And finally, these parts constitute a continuum. In short they are conceptual parts of a space that is in fact a unity.

After the period of the "Quaestiones" and "De gravitatione" Newton seemed never again to have been interested in epistemological issues. Whenever in his published works or in later manuscripts he does refer to epistemological problems he trots out those early opinions of the "Quaestiones" and "De gravitatione." I do not mean by this that those opinions were inoperative in his thoughts on physical matters after that early period, for I believe that they were far more central to his methodology than the "Hypotheses non fingo" of the Principia is generally taken to be. I hope that the preceding sections have in some small way indicated this involvement of his early ideas in his later thought, but a full evaluation of the role of these views on Newton's mature thought must be the subject of another work.

Berkeley's Criticisms

Given whatever insights we have achieved into Newton's epistemology and metaphysics in the above, are we in a better position to appraise some of the Berkelean criticisms of Newton's science?[19]

Berkeley misunderstood Newton's methodological principles by construing them as an acceptance of his own principle that to exist is to be perceivable. He then reproached Newton for not being consistent in his application of that principle. In particular he objected to Newton's use of the concept of force and his adherence to a notion of absolute space and time.

Newton was both closer to and further from Berkeley than Berkeley realized. They were both objective idealists who believed that God was far more responsible for those things we called bodies than any materialist could allow. Furthermore they both accepted similar methodological principles. It was the latter that led Berkeley to consider Newton a kindred soul, whereas, in fact, their grounds for adopting those principles were radically different. It was the former, however, that marked the real similarity between them, but Newton's metaphysical views, being unknown to Berkeley, could not figure in his appraisal of Newton's position.

Let us consider some of the similarities and differences in Newton's views as expounded in "De gravitatione" and Berkeley's views as expounded in the Principles of Human Knowledge. Berkeley's principle that to be is to be perceived (or, as expanded, to be perceivable) is present in Newton not in its epistemological form but as a condition for something being a body, i.e., as an essential quality. But for Newton it is one condition among others, and most importantly there must exist a region of space which has this power to produce sensations in created minds. Thus for Newton there is an intermediary between God's mind and ours, and that intermediary is space. This space exists independently of our perception of it, in fact we cannot observe space itself at all. Space is a passive product of God's existence, not an active product of His will. Bodies, on the other hand, have been endowed with a power to produce sensations, and are therefore active, unlike Berkeley's ideas. If we allow that Newton did really think that "basic" forces like attraction were also powers given to bodies by God, we can see that Newton grounded forces in that which he regarded as active, and not, as Berkeley thought, in that which is passive.[20]

What misled Berkeley was Newton's reluctance to make his position as an immaterialist known and his consequent hiding behind the "Hypotheses non fingo." This way of putting it is perhaps misleading. I am not claiming that Newton didn't believe in the "Hypotheses non fingo" and used it only as a dodge; that would be untrue. But he did not hold it as a consequence of a general epistemological position either. It was a prudential maxim that was required by his failure to complete the theological program--to determine which qualities were really essential to bodies. Newton's metaphysics had to remain in the background not because it was metaphysics but because it was incomplete. The metaphysical view did not yield the grounds for distinguishing between real and pseudo qualities in all cases. Empirical findings had to be irrelevant in the end since the correct interpretation of those findings rested squarely on the prior distinction between real and pseudo qualities. Those findings were stated by Newton in terms of those qualities which he could safely say were real since they were generally accepted as such by his contemporaries. When any explanation seemed to require the application of those qualities which he thought were real but could not establish as such, he would say that his concern here was not with the causes but with framing the law which the phenomena exhibited, and that he did not frame hypotheses. If he were to assert that such qualities, attraction for instance, were real without being able to offer grounds independent of the specific phenomenon which such an attribution would explain, he would be thought guilty of invoking occult qualities. That Newton was correct in thinking that this was the position his contemporaries would take is borne out in that it is precisely what Leibniz thought after discerning that Newton had made gravity a primary quality in the Principia, whether Newton admitted it or not.[21]

Berkeley and Newton both invoke God to account for those objects we call bodies. But as the Halls have written, " . . . Berkeley, to whom it was inconceivable that anything should exist unperceived by a sentient being, invoked God who perceives everything in order that matter should exist. Newton, on the other hand, denied matter in order that God should exist. The scientist was more a theologian than the philosopher."[22]

Conclusion

What has been determined regarding Newton's early epistemological thought is that it is largely constructed from the ideas he found in the works of the various authors we have considered; and that, it is characterized by the search for absolute criteria for the determination of which qualities are the primary qualities and the incongruous acceptance of certain procedural precepts on purely pragmatic grounds.

Newton's healthy respect for scepticism came from Galileo, Boyle, Descartes and principally Glanvill.

His faith in the ultimate success of science came from Galileo, Boyle and Glanvill. His general notion of dealing with the problems of perception through a metaphyscial monism came from Hobbes, while the general character of that monism was derived from More. His notion that the problems of perception might be avoided by adopting the primary-secondary quality distinction came from Galileo, Boyle and Descartes.

Newton was not an original thinker in epistemology, though he clearly was one in metaphysics. In the end, however, his patchwork epistemology served its purpose because he was led to adopt certain prudential principles in the face of his inability to solve his epistemological difficulties; and these principles kept the involvement of his metaphysics in his science to a minimum.

Those metaphysical and epistemological views were to the end of his life those that he had adopted sixty years earlier during his student years and immediately thereafter.

NOTES

CHAPTER IX

[1]"De gravitatione," p. 141.

[2]R. J. Forbes, "Was Newton an Alchemist?" Chymia, vol. II, (1949), p. 29.

[3]Frank E. Manuel, The Religion of Isaac Newton, (Oxford: Clarendon Press, 1974), p. 21.

[4]Ibid., pp. 21-2. [5]"De gravitatione," p. 137.

[6]In a memorandum by David Gregory headed, "In the new Edition of Newton's Philosophy these things will be done by the Author," Gregory writes, "He [Newton] will show that the most ancient philosophy is in agreement with this hypothesis of his as much because the Egyptians and others taught the Copernican system, as he shows from their religion and hieroglyphics and images of the Gods, as because Plato and others-Plutarch and Galileo refer to it-observed the gravitation of all bodies toward all." Quoted from item 461 Memoranda by David Gregory, Newton Correspondence, vol. III, p. 384.

[7]Principia, p. 398.

[8]I. Bernard Cohen, Franklin and Newton, (Philadelphia: American Philosophical Society, 1956), p. 585.

[9]See Principia, pp. 544-7. [10]Opticks, pp. 370, 400-6.

[11]Samuel Clarke and G. W. Leibniz, The Leibniz-Clarke Correspondence, ed. H. G. Alexander (Manchester: Manchester University Press, 1956), p. 14.

[12]Principia, p. 547. [13]Ibid., p. 546.

[14]John Locke, An Essay Concerning Human Understanding, trans. A. C. Fraser, (New York: Dover Publications, 1959), vol. II, pp. 321-2; Also mentioned in Alexandre Koyré, Newtonian Studies, (Chicago: University of Chicago Press, 1968), p. 92.

[15]Principia, p. 6. [16]Ibid. [17]Ibid., p. 8.

[18]Ibid., p. 6.

[19]Berkeley thought very highly of Newton but felt that he was not above criticism. The following quotations are taken from George Berkeley, The Works of George Berkeley, eds. A. A. Luce and T. E. Jessop, (London: Nelson, 1951), vol. I, p. 44, vol. IV, p. 140, vol. IV, p. 114 and vol. II, p. 272, respectively:

> I see no wit in any of them but Newton, The rest are meer triflers, meer Nihilarians.

> I have a high value for those learned remains of that great man [Isaac Newton], whose original and free genius is an eternal reproach to that tribe of followers who are always imitating but never resemble him.

> I freely own that Sir Isaac Newton hath shewed himself an extrordinary mathematician, a profound naturalist, a person of the greatest abilities and erudition. Thus far I can readily go, but I cannot go the lengths that you do. I shall never say of him as you do, Vestigia pronus adoro (p. 70). This same adoration that you pay to him, I will pay only to truth.

> . . . let Sir Isaac Newton, or any other man, be heard only so far as his opinion is supported by reason . . .

[20]For an excellent discussion of Newton's views in this repect see J. E. McGuire, "Force, Active Principles, and Newton's Invisible Realm," Ambix, vol. XV, no. 3, (Oct. 1968), pp. 154-208.

[21]In this connection see Newtonian Studies, pp. 139-48.

[22]Unpublished Scientific Papers of Isaac Newton, p. 81.

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