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JOHN MICHELL'S THEORY OF MATTER AND JOSEPH PRIESTLEY'S USE OF IT

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ABSTRACT

John Michell (1724-1793) developed a theory of penetrable matter in which a bi-polar (attractive and repulsive) power constituted substance, and made itself sensible through the properties of matter. His sensationalist epistemology was similar to Locke's, though he denied the essential passivity and impenetrability of matter which both Locke and Newton had espoused in favour of a monist synthesis of matter and power. Michell supposed that immediate contact and the mutual penetration of matter were not absolutely prevented but only inhibited by repulsive powers at the surfaces of bodies, and he explained light's emission, momentum and resulting ability to penetrate transparent substances by the interaction of the powers of light particles with the surface powers of luminous bodies and receiving bodies.

Joseph Priestley (1733-1804) adopted many of Michell's ideas on matter and light, and described them in his History of Optics (1772). Michell's friendship, from 1768, stimulated Priestley's interest in theory of matter, and helped him see its potential significance. He accepted Michell's ideas on penetrability, immediate contact, and the basic role of powers, as well as the epistemology which underlay these ideas; and Michell thus provided him with the means whereby he could attempt to redefine and explicate his physical and metaphysical ideas. Priestley extended Michell's theory and epistemology of matter, applying it in psychology and metaphysics as well as natural philosophy to arrive at an implicit monist system of powers ascending from the physical powers of attraction and repulsion through chemical and biological powers to the powers of mind, with all the powers

created and sustained by the powers of God; and he thus integrated the perceiving human mind and perceived substance in a dynamic metaphysical system which owed much to the ideas of Michell.

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PREFACE

I wish to thank Dr. Marie Boas Hall, my thesis supervisor, for her patience and her invaluable assistance in the preparation of this thesis.

The following kindly gave me permission to look at relevant manuscript and printed material: His Grace, the Duke of Devonshire (the Michell-Cavendish correspondence at Chatsworth); the Rare Books Department, University of California at Berkeley (microfilm copies of Roger Boscovich's letters from England in 1760); the Nottinghamshire County Record Office (Savile of Rufford and Foljambe Manuscripts, and the Bishop's Transcripts of Eakring Parish Registers); the Royal Astronomical Society (Herschel Papers); the Institution of Civil Engineers (Smeaton's Machine Letters); the British Museum; the American Philosophical Society (copy of a letter from John Michell to Sir Charles Blagden; the Berkshire County Record Office (several Michell-Savile letters); the Public Record Office; the Guildhall Library; Cambridge University Library; the Lyon Playfair Library (Imperial College); Senate House Library (University of London); the Science Museum Library; the British Museum (Natural History); and Dr. Williams' Library. I would like to thank the owners, custodians and staff of these collections for their kindness and assistance during my research.

I would like to thank the following at the University of Toronto for their generous assistance: Gordon Elliott for his suggestions of sources concerning the Michell-Savile connection; Professor James MacLachlan; Professor Kenneth O. May; and Professor Trevor Levere, who first pointed out to me the non-Boscovichean character of Priestley's theory of matter, and thus

initiated my interest in the origins of Priestley's theory.

Professor George Grinnell of McMaster University was the first to teach me history of science, and his course and his excellence as a teacher inspired me, among others, to study the subject at the postgraduate level. Larry Stewart, who studied with me under Professor Grinnell, and at the University of Toronto, provided me with many helpful suggestions throughout my research on this thesis.

I wish to thank Dr. R. Finaldi for his help with translating the Boscovich letters; Mrs. Barbara Nuttall and Mrs. Joan Vincent for their assistance concerning the Michell family; Dr. R. A. Harvey for information concerning Michell and Cavendish; and Mrs. Jennifer Hardy-Smith for typing the titles of this thesis.

My thanks to the members of the Department of the History of Science and Technology at Imperial College for their many kindnesses, questions and suggestions.

I would like to thank particularly Alison Yeomans and Riz Shakir, Ali for typing this thesis from an often illegible and constantly changing text, and both her and Riz for their friendship, assistance and encouragement.

INTRODUCTION

In a letter which he wrote to his friend John Michell in 1785, the civil engineer John Smeaton expressed the wish that Michell might "unravel" some "enigmatical" remarks which he had recently made on the physical structure of the eye.[1] He seems to have taken for granted the "abstruse" nature of his friend's pronouncements, and assumed that there was much substance hidden beneath apparently brief and cryptic remarks.

To the modern historian of science, as to John Smeaton, the problem of "unravelling" John Michell is a difficult task, and

one undertaken with the assumption that there is something to be found which can justify the effort. L.L. Whyte's remark in Roger Joseph Boscovich, (London, 1961)[2] that Michell was perhaps one of the great matter-theorists of the eighteenth century suggested to me that Michell might well repay the effort involved in studying his life and work. Two historians of science in the last decade have published articles on Michell's scientific career which have expanded considerably our knowledge of the life of this "enigmatical" man,[3] and much remains to be done.

Michell's "abstruseness" and his concomitant reluctance to publish concerning his scientific research are the principal reasons for the relative neglect he has received, despite recognition from contemporaries and later historians of science of such accomplishments as the discovery of the inverse square law of magnetism, the invention of the torsion balance, the founding of the science of seismology with his method for determining the epicenter of earthquakes, his determination of the strata of England, and his development of the theory of the penetrability of matter.

As increasing interest in Michell leads to the discovery of more material and to a more thorough awareness of the breadth and depth of his scientific and technological achievements, the sources of his ideas become somewhat clearer, as do the means whereby he utilized his practical experience with the properties of matter and his theoretical knowledge of mathematics, physics and philosophy to arrive at what amounts to virtually a revolution in theory of matter.

The first half of this thesis is concerned with what Michell thought about the nature of matter, and how he came to that view through a combination of experimentation, observation, reasoning, and the adaption and transformation of the physical, epistemological

and metaphysical ideas of Locke and Newton.

The principal first-hand source we have for Michell's "doctrine of attractions and repulsions" and his dynamic theory of matter is Joseph Priestley's History and Present State of Discoveries relating to Vision, Light, and Colours, (London, 1772). This work was in part the produot of collaboration with Michell between 1768 and 1772, and Priestley acknowledged his debt to Michell in the History.

Priestley also acknowledged the importance of the theory of point-atoms or "puncta" advanced by Roger Joseph Boscovich; but I hope to show that Michell was the chief formative influence on Priestley's developing theory of matter. Priestley's own theory, and even his reading of Boscovich's theory were principally shaped by the ideas which Michell had imparted to him. Priestley's discussion of Boscovich in fact points implicitly to differences between Michell's and Boscovich's theory over basio physical, epistemological and metaphysical questions, and although Priestley assumed the theories of the two men to be virtually identical, his misinterpretation of Bosoovich, influenced, I hope to show, by his earlier familiarity with Michell's ideas, helps to clarify those very differences.

Priestley adopted and applied Michell's dynamio and monistio theory of substance to psychology, metaphysios and theology in the mid-1770's, and its influence can be seen in the importance ascribed to properties and powers in some of his other work of the period. The second half of this thesis accordingly deals with Priestley's adoption, presentation and application of Michell's theory of matter.

CHAPTER ONE

MICHELL, SAVILE AND PRIESTLEY

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There are three principal accounts of the life and scientific career of John Michell: Agnes Mary Clerke's article "John Michell" in the Dictionary of National Biography (1888), Archibald Geikie's Memoir of John Michell (1918), and Clyde L. Hardin's 1966 article "The Scientific Work of the Reverend John Michell," in Annals of Science.[1] None of these is exhaustive, though each mentions major dates and events in his academic and scientific career.

Michell's published scientific papers and his Treatise of Artificial Magnets (Cambridge, 1750) provide valuable information concerning his scientific ideas, but give few details about his personal life or his scientific career as such. Letters to and from Michell, some already referred to in discussions of Michell, are invaluable for his life and career, while correspondence of the family of Michell's patron and lifelong friend Sir George Savile (1726-1784), Whig M.P. for Yorkshire (1759-83), great landowner, investor, and patron of science, throws additional light on many aspects of Michell's life.

Michell was born on Christmas day 1724, in all probability at Eakring, Nottinghamshire, where his father, Gilbert Michell, rector of the parish, baptised John, his first child, on 21 January 1724-5.[2] Gilbert Michell had two more children by his first marriage, Gilbert (1726-92) and Mary (1728-92). By a second marriage, to Hannah Woodhouse in 1752, he had two more children: George (born in 1754) and Elizabeth (born in 1756). John Michell was raised in Eakring, and at some time after his ordination as deacon in 1749 served as curate in his home parish.

Michell entered Queens' College, Cambridge in 1742, matriculating in the same year.[3] He graduated bachelor of arts in 1748, master of arts in 1752, and bachelor of divinity in 1761. He was a fellow of Queens' from 1749 till 1764, college lecturer in arithmetic (1751), geometry (1753), Greek (1755 & 1759), and Hebrew (1759 & 1762), and a tutor of the college from 1751 to 1763. He served as censor in theology from 1752 to 1754, as censor in philosophy and examiner in 1760, and in addition held several offices in the administration of the college. After his ordination as a priest in 1760 he served as rector of St. Botolph's, Cambridge, a living in the presentation of his college, and remained as

rector there until 1763.

During his years at Cambridge Michell came to know a number of important scientists and instrument-makers in Cambridge and London. At Cambridge one of his acquaintances was John Hadley (1731-1764), who entered Queens' in 1749, and became professor of chemistry in 1756. Hadley was one of Michell's sponsors for fellowship in the Royal Society in 1760. He was the nephew of John Hadley, the mathmatician, who had developed Hadley's quadrant; and Michell published in 1765 a paper in which he proposed a method whereby that insrument could be used in navigation and surveying.[4] Michell was also acquainted with Charles Mason, Woodwardian Professor of Geology,[5] and one may speculate that perhaps Mason introduced Michell to the study of geology in the 1750's, and may have helped him to obtain the Woodwardian professorship when he himself stepped down in 1762. As early as 1758[6] Michell had circulated in draft form the paper on earthquakes which was read to the Royal Society in 1760 and helped secure him election to the Society, and undoubtedly also to gain the Woodwardian chair two years later. He held the chair until his departure from Cambridge in 1764, at which time his impending marriage necessitated withdrawal from both his fellowship and the chair.

Michell was also becoming acquainted with scientists in London from the 1740's on. He seems to have been a guest of the Royal Society dining club in July 1748,[7] and dined there many times during the following four decades. He apparently knew by 1749 or 1750 Gowin Knight (1713-1772), the magnetic experimenter and instrument-maker, and John Smeaton (1724-1792), the great civil engineer.[8] During the 1750's, if not before, Michell became acquainted with important researchers in electricity, and himself

provided an introduction for one of the greatest electricians, Benjamin Franklin, to Matthew Boulton in 1758.[9] There is a letter extant from Michell to the electrician and painter Benjamin Wilson dated 1754,[10] and his friendship with William Watson, another great electrical experimenter perhaps dated from this period. He certainly knew of, and probably had met John Canton by this time.

Michell's academic career ended and his personal life changed in 1764 when he left Cambridge after twenty-two years as a student, fellow and instuctor. On 22 August 1764 he married Sarah Williamson of Rolleston, Nottinghamshire. She gave birth to a daughter, Mary, Michell's only child, on 1 August 1765, but died later in the same year. Michell had been appointed rector of Compton in Hampshire in 1763, and in 1765 he was transferred to the rectory of Havant in the same county. In 1767 his friend Sir George Savile presented him to the rectory of Thornhill in Yorkshire where he remained until his death in 1793. In about 1767 he married Ann Brecknock of Thornhill, and she survived him until 1818.

Michell's first scientific work was a Treatise of Artificial Magnets (Cambridge, 1750), and he did not publish again until 1760, when his paper on the cause of earthquakes appeared in the Philosophical Transactions. His work in magnetism and geology was cited in the successful recommendation put forward in 1760 for his election to fellowship in the Royal Society.[11]

The mid-1760's saw evidence of Michell's practical knowledge of mathematics and mathematical instruments. In 1765 he published the brief paper mentioned above outlining a method of using Hadley's quadrant for surveying; and in 1767 appeared a paper concerning the determination of the longitude.[12] He also served as one of the six commissioners appointed by the Board of Longitude in 1765

to assess John Harrison's fourth chronometer.[13]

In 1767 Michell published his first major astronomical paper, "An Inquiry into the probable Parallax, and Magnitude of the fixed Stars, from the Quantity of Light which they afford us, and the particular Circumstances of their Situation."[14] His acquaintance with Priestley begun in 1767 or 1768 provided the occasion for the further development of his views on light and matter, which Priestley acknowledged and described in his History of Optics, (London, 1772).

Michell's years at Thornhill were productive, and he continued his work in optics and astronomy, publishing another major astronomical paper in 1784, and engaging in the 1780's in an attempt to build a much improved ten-foot telescope. He devised an experiment using a torsion balance which he had built to "weigh the world," and mentioned this in a letter of 1783 to Henry Cavendish;[15] and Cavendish later acquired and adapted the torsion balance which Michell had built, to use in his own 1798 experiment of weighing the world.[16] Michell's letters from the Thornhill years included, for example, detailed discussions of telescope design with William Herschel and Henry Cavendish,[17] and his observations on geology in a letter of 1785 to Charles Blagden.[18]

During his later years at Thornhill, Michell enjoyed the company and advice of his brother Gilbert, who co-operated with him in his botanical experiments, and had several hothouses built at the Thornhill rectory.[19] Gilbert Michell had been apprenticed in 1742, the year his brother entered Cambridge, and had had success in a career in London in partnership with Nathanael Thomas, later an alderman in the City. He eventually retired to Thornhill; and his sister Mary also spent her later years at Meanhill, near

Thornhill, where she died in 1792, the same year as Gilbert and the year before John. John Michell's daughter married Thomas Turton, later baronet and Member of Parliament for Southwark, in 1786, and they had five children. Michell's scientific instruments were sold by Turton after his death, with his great ten-foot telescope being bought by William Herschel,[20] and his torsion balance for weighing the world eventually reaching Henry Cavendish. Nothing is known of the whereabouts of Michell's scientific papers apart from the surviving manuscript letters and the published papers and letters.

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Sir George Savile, eighth baronet (1726-1784), was Michell's lifelong friend, and his scientific and ecclesiastical patron. Some letters in the Savile papers at Nottingham throw a great deal of light on the Savile's friendship with and patronage of Michell.[21]

The ancient family seat at Thornhill had been destroyed in the Civil War. The family still had extensive holdings in that area during Sir George's lifetime, and he had great influence as a landowner, colonel in the militia, and M.P. for the county (1759-83). The family had acquired Rufford Abbey in Nottinghamshire after the Civil War, and it was there that Sir George's

father, Sir George, seventh baronet, lived and raised his family until his death in 1743.

The parish of Eakring, near Rufford Abbey, was in the presentation of the Saviles, and in 1722 the seventh baronet had appointed Gilbert Michell, John's father, to the rectory there. Sir George valued highly the friendship and counsel of his neighbour, and at one time selected Michell as an educational guardian of his son in the event of his own death;[22] and later named him one of the executors of his estate. Michell's letters to the seventh baronet's sister, Gertrude, in the Savile papers, show his continuing interest in the young Sir George's education and welfare.

The seventh baronet was a patron of science and a fellow of the Royal Society. He supported at least two of the projects of David Hartley (1705-1757), the physician, psychologist and philosopher, whose Observations on Man (1749) had an enormous influence on Joseph Priestley. Savile's name was listed among the subscribers to a fund established by Hartley for making public Joanna Stephens' remedy for the stone,[23] a preperation concerning which Hartley published several pamphlets. Hartley also supported the posthumous publications of the Elements of Algebra written by the Cambridge mathematician, Nicholas Saunderson,[24] and among subscribers listed in the work when it appeared in 1740 were Hartley and Savile. There was also listed a John Michell, who may perhaps have been the young friend of the Saviles, probably already showing his mathematical ability two years before he entered Cambridge.

Savile's son and heir followed his father's example, being elected a fellow of the Royal Society in 1748, by which date he had already done some experiments of his own in electricity, as a letter from Gilbert Michell to Gertrude Savile indicated.[25]

Savile entered John Michell's college, Queens', in 1745, by which time he had a very high opinion of his friend's ability.[26] One may speculate that Savile with his extensive family connections perhaps sought advancement for Michell in the College and the university. As early as 1748 he sought a government appointment for his friend, though the letter in which Michell's father mentioned this to Gertrude Savile did not state the type of position sought.[27] In 1749 Savile intervened with the Archbishop of York when technical matters threatened to postpone Michell's taking of holy orders.[28] In 1766, two years after leaving Cambridge, Michell wrote to Savile to thank him for his previous efforts in seeking appointments for him, and asked his help with the ministers of the Crown who would choose the Lowndes Professor of Astronomy at Cambridge, should a vacancy occur in that chair.[29] As it turned out, however, Michell never received the chair, nor held any position at Cambridge again.

Savile valued Michell's advice on a wide range of matters, just as his father had valued the elder Michell's. In a letter of 1759 congratulating Savile on his recent election to parliament in a by-election,[30] Michell described in considerable detail his recent experiments on bridge-building, in which he had assessed the properties of various types of stone, and constructed a scale model to test the strength and practicability of a new and simple extended arch design. He did not mention any specific project as the occasion for the research, so it is not possible to know whether Savile had sought his advice on any particular scheme, but Michell's extended description and beautifully drawn scale diagrams seem to indicate he expected an interested and intelligent response to his ideas.

Savile was perhaps interested in a project Michell undertook

in the mid-1760's. Michell's brief 1765 paper on the use of Hadley's quadrant gave as an example of its application the location of lighthouses at Spurn Point near the mouth of the Humber River, about twelve miles downstream from Hull.[31] The paper proposed a method for surveying harbours whereby an observer in a boat would use Hadley's quadrant and observe the angles subtended by various objects on the shore as seen from two different locations offshore. He proposed that the two lights at Spurn Point be relocated nearer the mouth of the Humber, so that pilots who might employ Hadley's quadrant to take their bearings might do so more easily and safely; with such a relocation when the new lights were built, the mouth of the Humber could provide the most secure place between the Tyne and the Thames during stormy weather.

This paper was published two years before Michell moved to Yorkshire, but the choice of Spurn Point to illustrate his proposals was probably not fortuitous. Savile was M.P. for Yorkshire, and may have acquired by this time his interest in the docks at Hull,[32] and would probably have been interested in anything to do with Humber navigation. Perhaps he was aware of Michell's interest in the application of Hadley's quadrant, and had mentioned Spurn Point to Michell.

The design and building of the Spurn Point lighthouses was entrusted to John Smeaton who had known Michell since 1750. In his account of the building of the Eddystone lighthouse in the late 1750's Smeaton mentioned some advice he received from Michell concerning a certain type of cement, though whether this advice was given then or at the time of writing in the 1780's is unclear.[33] Smeaton lived at Austhorpe near Leeds throughout his life, and the two men saw each other frequently after Michell moved to Thornhill. Smeaton perhaps mentioned the Spurn Point project to Michell in

the mid-1760's, and this may have led to Michell's paper; or perhaps Savile learned of it from Smeaton's appearances before House of Commons committees or through his own interest in Yorkshire. In January 1768 Smeaton, in a letter to Savile, discussed the amount of labour involved in raising water,[34] and gave an answer to a riddle, which suggests an acquaintance already well established, and personal as well as professional in nature. With such limited evidence one cannot establish the existence of any co-operation between the three men on the Spurn Point project; yet it is clear that Michell had taken an interest in the question by 1765, Smeaton later executed the project, Michell and Smeaton had known each other long before 1765, and Savile and Smeaton probably knew each other by the time the lighthouses were built.

Michell seems to have advised Savile on a number of technological and engineering matters in the Thornhill area. In a letter of 1772[35] Michell discussed the proposed plans for Thorp Arch Bridge, which apparently concerned Savile as M.P., and mentioned that he himself had not received the scale plans and the estimates which he had been promised. He suggested to Savile that a turnpike route through Thornhill would be the best route for a connecting link in a road to London from northwestern England and western Scotland. He also mentioned that he had visited Walker's foundries at Rotherham where he had made inquiries for Savile concerning the size of iron axle trees for wagons and carts, adding some detail concerning sizes and related matters, issues probably connected with the proposed turnpike extension.

In a letter of 1783[36] Michell advised Savile concerning a scheme for adding as an alloy in gold coins a semi-metal which would supposedly be too difficult to separate from the gold, so

that the melting down of the gold coins would cease. Michell ascribed the idea to the chemist Bryan Higgins, whom he regarded as able but often wrong-headed, and sought to show that even if the proposal were practicable it would do little or nothing to alter the economic factors which made the melting of coins or their export from the country virtually inevitable as long as any amount of money could be made from such operations.

Savile also relied on the financial experience of Gilbert Michell, who had had a successful career in London; and in 1781 after the two men had several discussions concerning the proposals of Lord North's government for the issuing of stocks, Gilbert Michell wrote two letters to Savile giving in detail his thoughts on the significance of the proposed terms of issue.[37] Savile's trust in the integrity and financial acumen of both brothers was also shown by his naming of them as two executors of his estate.[38]

To what extent Michell and Savile shared religious and political beliefs is uncertain. Savile was a whig in politics, supporting legislation easing the condition of protestant dissenters and Roman Catholics, favouring political reform, and supporting the American colonies in their fight for independence. Michell's letters offer virtually no mention of his political views apart from a letter written to Savile in August 1782, when the war with the American colonists was almost over.[39] Michell then expressed regret at the recent death of Lord Rockingham, one of the great Whig leaders, and briefly Prime Minister in 1782 after the fall of Lord North's Tory ministry. Michell had hoped Savile might be able to procure him preferment through his influence with Rockingham, and hoped that Savile would continue his efforts on his behalf if any other "friends" should come into power. He doubted that men of Rockingham's integrity would succeed to po-

sitions of responsibility in the House. Michell's chief concern was that the war with America should end as soon as possible; he stated that he had always opposed the war as one of "pride & injustice" and a piece of "folly & indiscretion from the beginning", and expressed the wish that it might be ended as quickly as circumstances would permit. This statement of sympathy with the American colonists, particularly in the light of the remark about his attitude being such from the beginning of the conflict, places him on the Whig side with regard to the war, a very important clue as to his political leanings, as the war was one of the most important and divisive issues in late eighteenth-century politics.

Savile and Michell also appear to have had similar attitudes towards dissent. Savile's support of Priestley's scientific work and his collaboration with Priestley in support of the dissenting cause during the 1770's when Priestley was librarian to Lord Shelburne show his willingness to support both the scientific research of a well-known and controversial dissenter with his own purse and the religio-political aims of dissenters with his time and political influence. Savile was also an admirer of the controversial dissenting theologian and preacher, Theophilus Lindsey, who was a colleague and a close friend of Priestley, and a friend of Michell's by 1754.[40] Savile was apparently a frequent visitor to the Essex street chapel in London where Lindsey (and occasionally Priestley) preached; and he left Lindsey a bequest in his will.[41]

His appointing of Michell to the rectory of Thornhill perhaps indicates agreement between the two men on religious questions, and this becomes more likely in view of Michell's very close collaboration with Priestley on optics and theory of

matter during the late 1760's and early 1770's, when Priestley was becoming a very controversial clergyman, and a known unitarian, with all the opprobrium such a position could hold in the eighteenth century. It was to Priestley that Michell outlined both his theory of the penetrability of matter, and even more importantly for an understanding of his metaphysical views, the reasoning whereby he arrived at the notion of the "immateriality of matter", with its implicit rejection of the existence of immaterial spirit. This latter notion, as shall be seen later, was central in Priestley's development of a materialist metaphysical system, and its origination with Michell suggests a willingness on the latter's part to speculate boldly on very sensitive metaphysical questions. This type of boldness seems to have been typical of the influential dissenting and latitudinarian Anglican thinkers whom Savile and Michell knew, and was also in keeping with the "rationalist" metaphysics and epistemology espoused by Michell, which will be discussed in detail.

In summary, Savile's influence on Michell was most obvious in his career as a clergyman and technologist; while his attempts to gain academic preferment for his friend appear to have failed completely, and his influence on Michell's scientific research is difficult to estimate with the scanty evidence. Both Saviles, father and son, appear to have encouraged their friend in his scientific pursuits, and both were in all probability interested and knowledgeable amateurs of science. A more tangible example of their friendship for the Michell family was the appointment of Gilbert Michell to Eakring, which permitted John Michell to enjoy the stimulation of the Saviles' company, and probably the use of their library, and the possibility of being able to attend Cambridge because of his father's comfortable income. The eighth

baronet's appointment of John Michell to the rectory at Thornhill permitted him the comfort and leisure to pursue his scientific and technological interests without great concern for financial matters, despite his occasional complaints to friends in the 1780's about shortage of money for his experiments with telescope design and construction.[42]

Savile's influence was most noticeable in the letters Michell wrote to him, with their discussion of bridge design, turnpike routes, changes in the coinage, and similar matters which concerned Savile as a public figure. Savile's interest in Michell's ideas and his desire for practical advice probably stimulated Michell to pursue these interests in which the practical application of his extensive mathematical and scientific knowledge was required. At the same time these practical concerns, particularly concerning the strengths and uses of such materials as stone for construction helped further his knowledge of the properties of substances which had already been founded with his geological observations and his work with iron and steel in the making of artificial magnets. The great issue in Michell's work on matter and powers became the problem of linking the properties of matter and the powers of nature in a single theory of matter; and the encouragement which Savile offered, by way of being an interested listener, ecclesiastical patron, and a public figure in need of advice on practical measures in the realms of technology, applied science and mathematics was very valuable. Their apparent sharing of similar attitudes in politics and religion further increased the area of common interest between them already created by many years of friendship between the two men and their families.

(III)

The second half of this thesis concerns Joseph Priestley's use of Michell's theory of matter between the first meeting between the two men in 1767 or early 1768 and the appearance of Priestley's Disquisitions Relating to Matter and Spirit in 1777. In 1767, the year in which Michell moved to Thornhill, Priestley moved to Leeds to assume the ministry of Mill Hill chapel, and in early 1768 Priestley wrote to John Canton that he was seeing Michell "pretty often".[43] Priestley's life has been described many times and this section is only a brief outline, with particular emphasis on the period from 1767 to 1777.

Priestley was born at Fieldhead near Leeds in 1733 and went to school nearby.[44] In 1742 his widowed father entrusted the care of Joseph, his eldest son, to his sister, Mrs. Keighly, whose concern for her nephew took expression in her care that he be well educated and that he enjoy the company of the dissenting clergymen of various persuasions who frequented the home of this fervent Calvinist lady. In 1752 Priestley entered the dissenting academy at Daventry at his own request, having already moved from the Calvinist position of his aunt and the rest of his family and being anxious to enter Daventry rather than the more strictly Calvinist academy at Mile-End. He studied at Daventry until 1755 and found the atmosphere of controversy very stimulating; there he was introduced to David Hartley's writings which convinced him of the doctrine of philosophical necessity and its compatibility with Christianity. He later observed that Hartley led him to conclude that one could be a Christian, a materialist and a necessarian at the same time; and his explication of Hartley's system as transformed by the dynamic theory of matter

which Michell imparted to him formed perhaps the most important intellectual accomplishment of his life, and one which occupied much of his time and energy through the mid-1770's.[45]

After he left Daventry in 1755, Priestley served as minister at Needham Market in Suffolk till 1758, and from then until 1761 he led the congregation at Nantwich in Cheshire, where he also instructed a small group of students in scientific subjects. In 1761 he entered the staff of the dissenting academy at Warrington, though as an instructor in belles lettres rather than in mathematics and natural philosophy which he said in his Memoirs he would have preferred.[46] While at Warrington he published several works in history, grammar, education and government, and began the preparation of his first scientific work, the History and Present State of Electricity, with Original Experiments, (London, 1767). He also met in London in 1765 and early 1766 the great electrical experimenters William Watson, John Canton and Benjamin Franklin (all of whom, as we have seen, knew Michell by this time), and they suggested to him that he write a history of the subject, provided him with books and accounts of their own experiments, and mentioned experiments that he might attempt.[47] They supported his election to fellowship of the Royal Society in 1766 and followed with interest the abortive proposal in the Royal Society to award him the Copley Medal for his History, the work eventually being disqualified because it was not an experiment as required under the terms of Sir Godfrey Copley's will.[48]

In 1767 Priestley moved to Leeds and soon afterwards met Michell, though who introduced them is not known.[49] There soon began the collaboration between the two men in optics and theory of matter which led to the publication of the History of Optics in 1772, with Michell playing a role similar to that

of Franklin, Watson and Canton with regard to the History of Electricity. Michell described to Priestley his experiments and calculations concerning particles of light, and his theory of the penetrability of matter based on the monistic assumption that matter consisted only of powers. Priestley described these ideas in the History and acknowledged warmly Michell's contributions to the work, which included textual emendations and proof-reading of the text.[50] Priestley's adoption and adaptation of Michell's ideas on matter and powers were both prior to and more important than the influence of the theory of matter put forward by Roger Boscovich in his Theoria Philosophiae Naturalis which Priestley read late in the preparation of the History, and with the basic physical assumptions of which Priestley and Michell disagreed. This will be discussed in detail in chapters four, five and six of this thesis.

A political pamphlet which Priestley wrote in 1768 was apparently the occasion for the beginning of his friendship with Michell's friend and patron, Sir George Savile;[51] and the collaboration of Priestley and Savile on political issues, particularly concerning the dissenting cause, became more extensive when Priestley left Leeds in 1773 to become librarian to the Earl of Shelburne, one of the great Whig leaders, and briefly Prime Minister in 1783. The post with Shelburne, and the financial security which it provided enabled him to pursue his researches in pneumatic chemistry which had begun in earnest while he was at Leeds, a paper on "Different Kinds of Air" (1772) having won him the Copley Medal.[52]

The new position also permitted him to pursue his interest in psychology, metaphysics and theology, in which fields his by then avowed unitarian beliefs and his materialism and necessarianism combined with his assumptions about the dynamic and

penetrable nature of matter. In the mid-1770's he produced a critique of the "common sense" philosophy (1774),[53] a defense of Hartley's theory of the mind and associationist psychology (1775); and in his Disquisitions Relating to Matter and Spirit (1777) he put forward most extensively the controversial consequences of his developing metaphysical system with its monistic synthesis of matter and spirit suggested to him by Michell.

Priestley continued to work and publish in chemistry and the physiology of respiration, and his theological publications occupied part of his time during the 1780's while he lived at Birmingham. His home was destroyed in 1791 because of his radical political views and support of the French revolutionary cause, but his research and publications continued during his last three years in England, and throughout his years of self-imposed exile in the United States, until his death there in 1804.

CHAPTER TWO

MICHELL'S IDEAS ON MAGNETISM AND HIS THEORY OF 'MOLECULAR MAGNETS'

(1)

In 1750 Michell published *A Treatise of Artificial Magnets; In which is shewn An easy and expeditious Method of making them, Superior to the best Natural Ones*, printed by J. Bentham, printer to Cambridge University. A second edition appeared in 1751 with minor alterations; and a French translation was published by Father Antoine Rivoire in Paris in 1752, in the same volume with Rivoire's translation of John Canton's 1751 work on a method of

making artificial magnets.[1]

The Treatise was Michell's first publication and linked the practical matter of the production of artificial magnets with the properties of iron and steel, culminating in what amounted to a theory of magnetical power, given under the more limited rubric of the properties of magnetical bodies. The Treatise is important to the understanding of Michell's scientific career because it involved him in a bitter priority dispute with John Canton which may have permanently affected his attitude towards scientific publication; because it shows his early thoughts on the connection between the properties of bodies and the powers of (magnetical) attraction and repulsion; and because it contains a number of concepts which he later elaborated more fully into a point-atomic theory of magnetic particles.

Firstly let us look at the Michell-Canton dispute. Both men developed methods of making artificial magnets about 1750, with Michell publishing his Treatise in 1750, and Canton producing in the following year a work entitled A Method of Making Artificial Magnets Without the Use of Natural Ones. Michell's method involved the moving of an armed magnet back and forth three or four times along six steel bars placed in a single line; and this was followed by a repetition of this "touching" process with the end bars placed in the middle, after which one placed the two bars once more at the ends, and touched them with the magnet.[2] Michell described a number of variants on this method including some which used natural and others which used artificial magnets. He believed that the so-called "double touch" method worked much better than the single touch, for the retention of the magnetic strength with the former method appeared to him to be much longer in duration than with the latter, although the "double touch" method is now known to

be no more effective than the single touch method.

Canton's method[3] involved the use of six soft and six hard steel bars, using an iron poker and tongs to stroke four of the soft steel bars on each side, after which one placed the other two lengthwise between two pieces of iron and placed the four magnetized bars perpendicularly on the other two, with the touching process being repeated. Then the hard bars were touched in a similar manner, and the entire series of operations was done once more for the bars in their parallel position between the pieces of iron, with horizontal strokes now replacing the vertical ones.

Thus both men proposed a "double touch" method, with the addition in Canton's case of the iron pieces. Canton claimed to have developed this method as early as 1747, while Michell later argued that Canton's method was basically his own (Michell's) method with the addition of the iron pieces, the idea of which he said Canton may have borrowed from du Hamel.[4] The dispute survived Canton's death in 1772, and as late as 1785 Michell raised the subject in a letter to the Monthly Review.[5] Even at that date the location and time of meetings, and the problems of "old-style" dating in connection with events thirty-five years earlier were being discussed, and the priority issue will probably never be solved, though the "double touch" method produces no better magnets than the "single touch" method.

More significantly for the history of the science of the period, John Smeaton and Gowin Knight believed and defended Michell's refutation of Canton's charges of plagiarism,[6] and remained his friends. Priestley knew of the dispute soon after he met Michell in 1767 or early 1768,[7] and came to favour Michell's claims even though assisting John Canton's son in his attempts to vindicate

his father's name after Michell's remarks in the Monthly Review in 1785.[8] It appears that Michell's scientific career was more affected by the dispute than Canton's, for Michell displayed a reluctance to publish concerning his discoveries for the rest of his life.

Secondly, let us look at Michell's discussion of the properties of magnetical bodies and their connection with the magnetical power itself. Although the Treatise was chiefly a practical work aiming at the cheap and convenient production of powerful artificial magnets,[9] the naming and description of the properties of iron and of various types of steel was nonetheless central to the work.

In outlining his ideas on magnetical bodies, he described "properties" of magnets and magnetical bodies rather than the "power" of magnetism as such, although he did speak of magnetic power in the work. His use of the term "properties" shows that he regarded the observation and analysis of bodies to which the power had been imparted or in which it occured naturally as the key to understanding magnetism. The power in itself is in a certain sense the property of such bodies, but not directly observable, and Michell seems to have regarded the most convenient, though indirect route to an understanding of the power as lying in the observation of bodies possessing it. To use the term Priestley later used in the History of Electricity[10] Michell appears to have sought "inlets" into the nature of the magnetic power through the properties of magnetical bodies.

One of the crucial properties of these bodies seemed to him to be their inability to absorb any more than a certain amount of magnetism. His experimental demonstration of the existence of a natural resistance of steel to magnetic power was very simple,

as follows.[11] He found that it required at first a force of six or seven pounds to separate two semicircular magnets which had been magnetized while in contact with each other, but after he had separated them once he was able to separate them with a force of only three or four pounds. He also found that a small armed single bar made magnetical with a wedge of iron in contact with it during the process could lift one-fifth more by means of the wedge than it could after the wedge and the bar had been detached from each other. From these two experiments Michell concluded that the cause of the loss of strength was not the methods used, but simply the inability of the steel to retain any more than a certain amount of magnetism.

Michell cited another experimental observation which seemed to him to confirm this hypothesis and also gave him a clue as to the reason for this phenomenon.[12] He found that two magnets placed with their like poles together could each cause damage to the other; and if several were arranged in this manner some might even have their poles reversed. Michell ascribed to hardness the fact that steel resisted the tendency of like poles to damage or convert each other:

> ...if we conceive any Magnet, as divided into several, by Sections parallel to its Axis,...each of these will be endeavouring to damage all the rest. Now, if we suppose, that the hardness of the Steel is able to resist this Endeavour, in some measure; this will very well account for any piece of Steel retaining its Magnetism to a certain degree, and for its not retaining any more than that: since after the Power is become so great, as to be an overmatch for the resistance arising from the hardness of the Steel, the Magnet must necessarily reduce itself to such a power, as shall be just a balance for that resistance.[13]

Thus the resistance which magnets possessed was a tendency to avoid damage by the like poles of other magnets;any excess magnetic power would damage the magnet, just as the power of each magnet section tended to damage its neighbouring section. The

hardness of the steel determined how much magnetism could be retained without damage, he reasoned; and in the case of the like pole of a stronger magnet being forced into contact with the like pole of a weaker, the damage occurred in the form of the conversion of the weaker. He seems thus to have implied the existence of two "powers" in magnetical bodies: a magnetic power, and a resistance to that power; the latter being able to eject any magnetic power which would exceed the strength of the resistance.

This resistance, he argued, was effected by the hardness of the steel, for if one accepted the above reasoning, soft steel would retain less magnetism and be more easily damaged than hard steel:

> ...And this is actually the Case; for a piece of spring-temper'd Steel will not retain near so much Magnetism, as hard Steel; soft Steel will retain still less; and Iron, which is the softest of all, scarce retains any....[14]

This phenomenon resulted from the different abilities of the various strengths of steel to retain magnetism; and this was directly related, in Michell's opinion, to the ease with which a given type of metal received magnetism, which was in ascending order of difficulty: iron, soft steel, spring-tempered steel, and hard steel.[15] This could be seen in the way in which spring-tempered magnets were more seriously damaged than hard steel magnets, if their like poles were placed together.

Michell suspected that better quality iron ore rather than different steel would provide further improvements in magnets:

> ... since different Steel, as far as has fallen under my experience, has made little or no difference; only that some has required greater exactness, or a greater or less degree of heat, in the hardening.[16]

Many good magnets had been made with soft or spring-tempered steel, he noted, from the mistaken assumption that they would have been better magnets if made with hard steel, for the latter,

he thought, kept more magnetism, and for a longer time, if made by his method.

Michell claimed to base his method on the principles of magnetism, or what he terms the "properties of Magnetical Bodies":

> ...some of which are very necessary to be known by those, who have a mind to try Experiments, and for want of the knowledge of which, many experiments on this subject have fail'd, or wrong conclusions have been drawn from them....[17]

Michell presented a list[18] of the properties of magnetical bodies which he had established by experiment, each property constituting an element in the basic knowledge which he thought requisite for successful magnetic experiments. He had initially planned to include in the Treatise a "theory" of magnetism which he "endeavoured to establish by Experiments", but had deferred this because it would have increased the size of the work drastically, and besides, the work was intended as a practical treatise.[19]

Michell set forth seven properties of magnetical bodies in the form of propositions, though leaving the proofs "till some farther opportunity offers."[20] The clarity of Michell's theoretical arguments in his description of the properties of magnetic bodies is noteworthy.

The bi-polar nature of magnets (proposition one) was already known; but Michell added that each pole of a given magnet attracted or repelled exactly equally at equal distances in every direction, and remarked in a footnote to the third proposition:

> This is a Property, which perhaps those, who imagine Magnetism to depend upon a subtle fluid, may not be very willing to admit, as being utterly inconsistent with such an Hypothesis; but it is capable of being proved by a great variety of experiments.[21]

Unfortunately Michell did not cite the experiments in this brief account; nonetheless his rejection of the "subtle fluid" hypothesis is clear. Boscovich in 1760 noted with approval that Michell's

theory of bi-polar magnetic particles utilized neither vortices nor fluids;[22] and clearly Michell had no more use for vortices and fluids ten years earlier.

He had also determined that the interposition of solid bodies did not affect magnetic power (proposition two),[23] and though he gave no experimental evidence presumably because of brevity, one may speculate that he was very careful in ascertaining this point, for it is one with important implications. It suggests that magnetism (as he said in connection with proposition three) is not a subtle fluid which could be impeded by a solid body;[24] and it also suggests that magnetism, whatever its nature (and Michell called it a "power") can pass unimpeded through solid bodies despite their apparent resistance to penetration which is the concomitant of their apparent solidity. His apparent certainty on the equal attraction and repulsion at equal distances in all directions was in marked contrast to his lack of absolute conviction about the inverse square law (proposition six)[25] for which he had seen considerable experimental evidence, and suggests he had ascertained the former by experiment.

A further example of the clarity of his argument can be seen in his separation of the statement of the equality in strength of two poles (proposition three) from his statement of the inverse square law (proposition six). His uncertainty over the latter was probably one reason for separating the two; yet the separation may also reflect an awareness that the two were not linked in any logically necessary manner. For example, one could conceive of an inverse square law of magnetism operating without the attractive and repulsive powers being equal and opposite. Michell had asserted the opposition and equality of the two powers;[26] but he was reluctant to state the inverse square law with certainty because he

felt he had insufficient evidence.

Michell's use of the inverse square law reveals his debt to Newton, and suggests a direct analogy with the power of gravitation which Newton found to operate according to such a law. The inverse square law also indicates Michell's "rationalism" in both its literal sense (from the term "ratio"), and in the more usual sense of a tradition viewing man's reason as an analogue, though finite and created, of the Divine reason, and as the means whereby man could come to know the "ratios" or "harmony" of the universe.

One other aspect of Michell's concept of magnetism was in the Newtonian tradition, namely the notion of power radiating outwards from a point-source. Michell was quite explicit on the source of magnetic power in a magnet:

> ...every Magnet has two Poles, (as they are called,) that is, two Points from which the attractive and repulsive powers seem to spread themselves, and to which they are directed; at the nearest parts to which, if other circumstances be the same, the Magnet always acts strongest....[27]

This brings us to the third aspect of Michell's Treatise, the use of concepts which were important in his later work. The concept of dual point-sources radiating attractive and repulsive forces was important in his theory of bi-polar magnetic particles, and in the Treatise he observed

> ...that the two Poles of an Artificial Magnet, of any Size, may be brought as near each other, as any one pleases, and yet the Magnet have a sufficient length in proportion to its bulk; as in the Annular and Horse-shoe Magnets hereafter described.[28]

Michell spoke of the poles of magnets as "points";[29] and as slightly distant from the ends of the magnets;[30] and if one reads the above statement with the substitution of "points" for "poles", one can conceive of two "points" being brought continually closer to each other, as close "as any one pleases". Michell's theory of magnetic particles seems to have been an explication of the result of

bringing two magnetic "points" as close as possible, as will be seen in the next section.

Michell observed that

> ...when the repellent Poles of a large Magnet and a small one are brought into contact, the small one shall sometimes have its Repellency changed into Attraction.[31]

This observation of a dynamic process, specifically the conversion of a repellent pole into an attractive one, was an interesting anticipation of the dynamic nature of his later theory of matter. He knew that an attractive and a repellent pole could be brought into contact, and this observation hinted at the possibility of a reversible dynamic process in which contact between like poles produced the transformation of one pole (that of the smaller and less powerful magnet) into its opposite. In his theory of magnetic particles in which polarized points were in contact, the process whereby they generate the powers which constitute matter was dynamic and the actual fact of contact played a significant role in the generation of these powers.

The dynamic character of Michell's conception of magnetic polarity becomes somewhat clearer in this discussion of the contact of like pole with like. The very notions of "attraction" and "repulsion" and of an "attractive pole" and a "repellent pole" are logically complex ideas, and it appears to me that the Treatise shows his full awareness of this complexity. The clarity with which he enunciated as separate items the closely related "properties" of magnetical bodies seems to indicate his concern that the principles of magnetism be as carefully and precisely described as possible. Accordingly, when he speaks of two repellent poles coming into contact, having already said that the poles repel like, we must assume that something overcame the tendency which the two poles have to repel each other. In the particular case

he mentioned, the contact resulted in the pole of the smaller magnet being converted, though he did not say how or why this occurred. It is as if the imbalance in strength of the two poles permitted the transformation of the less powerful when the initial repulsion had been overcome. Michell had stated that magnetism was always bi-polar, and it appears that in this case perhaps the bringing of the two unequal poles into contact resulted in the formation of a new "magnet" consisting of the repellent pole of the stonger as the repulsive pole and the repellent pole of the weaker as an attractive pole. This poses the question of why this would not occur if the two magnets had been of equal strength. The repulsion was overcome by the use of physical pressure which forced the two repellent poles into a situation which was not one of balance or equilibrium, because their natural tendency was to repel each other. In the case of equal strengths, there was no way of altering this essential imbalance, whereas in the case of one being stronger, the force of the stronger seemed to restore the "balance" of nature by transforming that which it was in contact with into an unlike pole.

Michell was dealing here with a situation in which contact was made difficult by repulsive powers, and he knew that physical pressure could overcome the resistance created by those powers. In this sense, then, the repulsive powers of the two magnets were mutually penetrable, with mutual penetration leading to contact and the reversal of polarity of one pole. Although Michell said this reversal did not always happen when one of the repellent poles was stronger than the other, nor why this should have been the case, it seems to me that he described a situation in which physical force overcame a natural resistance to penetration, an imbalance in powers resulted, contact was achieved despite that

imbalance, and a reversal of one pole restored at least partially the lost natural balance. Attraction and contact occurred naturally between unlike poles, and in this case some force or power of nature seems to have transformed the situation into one in which unlike poles were in contact.

The question of immediate contact and its possibility was one of great importance in Michell's theory of matter, and this was his first discussion of the subject, even though placed in the context of magnetic polarity. He spoke of contact between poles of a magnet in the Treatise without mentioning the problem of immediate contact, and even in the section just discussed, the problem was not explicitly mentioned. All that we can see is that Michell assumed in the Treatise the possibility of immediate contact between magnetic poles, and this even when the presence of two like poles created a tendency for the two poles to stay apart. This is important to keep in mind when assessing Boscovich's statement in 1760 that Michell denied the possibility of immediate contact.[32]

Closely related to the question of repulsive forces inhibiting immediate contact was the concept of resistance which Michell used when discussing the ability of a piece of steel to absorb the magnetic virtue. He found that the resistance could be lowered by the use of harder steel, which could absorb and retain more magnetic power than softer steel. He did not define the nature of this resistance but said only that steel had a power or tendency to resist and expel any magnetic power above a certain strength, so as to restore a balance which the excess magnetism destroyed. One can perhaps speak of this tendency of steel as a "repulsive" force or power in so much as it produced the expulsion of the magnetic power; but this leaves unanswered the question of how

a piece of steel absorbed the magnetic power in the first place. Michell stated that the presenoe of iron seemed to be a prerequisite for any body to become magnetical, whioh seems to imply that some property of iron permitted it to beoome magnetical. Yet the amount of iron in a steel bar does not seem to have been a consideration in Miohell's discussion of magnetization, for his main concern was the hardness of the steel as obtained by the tempering process used.

Soft steel, he said, "received" magnetism more easily, but did not retain as much magnetism as harder steel, and lost more readily what it did receive. The ability to retain magnetism was greater with the harder steel, though it received magnetism with more difficulty. The greater resistance of hard steel inoreased the difficulty of magnetization, but at the same time inoreased the ability to maintain the magnetic power once the resistance has been overoome. The key to the stronger magnets was therefore the inorease of hardness and resistanoe, for greater resistance permitted more magnetism to be retained. However if the magnetism was introduced in suoh a quantity as to become an "overmatoh" for that resistance, it was rejected, presumably because it did not find the hardness required for retention, and it was ejected until a balance between the resistance and the magnetic power was established. To use the metaphor of attraction and repulsion, steel attacted the magnetic power depending on the amount of hardness and resistance it possessed, and repelled any more magnetism than its hardness could retain. It is as if the hardness resisted penetration by the magnetic power, and was at the same time a prerequisite for its retention. The strength of the power of resistance (and hence of attraction or retention) was, in some manner unspecified by Michell, a property of steel which inoreased

with hardness. The power of resistance was an exact measure of the amount of magnetic power which the steel could retain, and was equal to the amount of force which the magnetic power had to exert to penetrate the resistance. As Michell argued in the Treatise, magnetism operated unimpeded by the interposition of solid bodies, and hence was presumably able to penetrate solid bodies. Therefore the retention of magnetic power required the penetration or overcoming of a power other than mere solidity, otherwise all bodies could become magnetical. Solidity was involved insofar as the hardness of steel was a decisive factor in determining the amount of magnetism which could be absorbed; but the presence of iron was the prerequisite for a body to become magnetical, being presumably responsible for the resistance to the magnetic power which permitted the body to become magnetical. Thus it appears that the resisting magnetic power was an essential property for a body to become magnetical; the greater the hardness, the greater was the resistance, and the greater the resistance, the more strongly magnetical the body could become. One can also note, in the light of Michell's remark quoted above about imagining the poles (in the form of points) of a magnet being moved together as closely as one wanted, that his idea of conceiving a magnet as divided into several parallel sections, if taken to its furthest conclusion, could result in infinitely thin magnets; and this combined with the concept of magnetic poles in the form of points being moved very close together would lead to the concept of magnet particles consisting of two oppositely polarized points which, once magnetized, would be held in their north-south magnetic orientation by the hardness of their steel. Michell did not take these concepts to this stage in the Treatise, though given their simplicity it is perhaps conceivable that he had developed these ideas by this

time, and left them unpublished because of considerations of brevity.

It is clear however that Michell used a number of concepts in the Treatise which resulted in a magnetic theory simpler and more comprehensive than those of his contemporaries. Perhaps the most interesting contrast is with the theory of magnetism put forward by his friend Gowin Knight in 1748 in An Attempt, To demonstrate, That all the Phaenomena in Nature May be explained by Two Simple Active Principles, Attraction and Repulsion..., (London, 1748). Knight supposed the existence of two types of particulate matter, one attractive and the other repellent. The "indefinitely small" repellent particles surrounded the larger attractive particles, and "will in Point of Contact repel with an indefinite Force."[33] Magnetism was caused by the circulation of this repellent matter, and its passage from one body to another caused magnetic attraction and repulsion;[34] depending on the amount of magnetism in two loadstones, the force of attraction varied as the distance, the square of the distance, the cube, and various other ratios.[35]

Michell had perhaps read his friend's discourse, and his own theory of magnetism shows a simpler approach to the nature of magnetism, with two types of matter being replaced by a single one and a single bi-polar power. This rejection of what he regarded as unnecessary suppositions of additional types of substance recurred throughout Michell's work, and became one of the principles of his theory of substance. As we have seen, Michell did not define exactly the relationship between the power of magnetism and the magnetical bodies which possessed it as a power; but he made it clear that magnetism was a property of a substance, namely iron and bodies containing iron, rather than a subtle fluid.

It is also interesting to note that Michell did not suppose in the Treatise as Knight had the existence of any repulsive force of indefinite strength, and that he supposed contact between magnetical bodies, even ones with like polarity, possible, though perhaps requiring some force to overcome that resistance. It is possible that Michell's rejection of subtle fluids with particles that were elastic and indefinitely repellent was a concomitant of what I have argued may have been his rejection of the impossibility of immediate contact. He seemed in the Treatise to attempt a synthesis of matter and the aetherial subtle fluid (at least in relation to magnetism), into matter and bi-polar power, and his apparent acceptance of immediate contact, particularly given Knight's specific rejection of it in a magnetic treatise of two years earlier, makes such a hypothesis conceivable.

In summary, Michell in 1750 conceived of magnetism as a bi-polar power, consisting of co-equal and exactly opposite powers of attraction and repulsion radiating outwards from a point-source somewhat away from each end of the magnet. The law of force appeared to be that of decrease as the inverse square of the distance. Any body containing iron could receive magnetism, but the amount that could be received depended on the hardness and resulting resistance to influence by magnetism of the steel.

(11)

By 1760 Michell had expanded his theory of magnetism and propounded a theory of bi-polar magnetic particles which he described to Roger Boscovich during the latter's visit to Cambridge in 1760.[36] In an essay of 1961 on Boscovich's Theoria Philosophiae Naturalis Markovic brought attention to a letter of Boscovich's describing Michell's theory, and spoke of Michell's "theory of 'molecular magnets'" noting that Michell thought repulsive forces appeared at small distances.[37]

Boscovich met Michell several times during his stay in England from May to December 1760. Both men were present at the weekly dinner meeting of the Royal Society dining club on 5 June,[38] and as the entire company was probably introduced to the distinguished visitor, it seems likely the two men first met there.

They definitely met and had long discussions at Cambridge where Boscovich went early in November. In a letter to his brother dated 14 November,[39] Boscovich said that Michell displayed some of his magnetic experiments to him, gave him a steel bar which he had artificially magnetized during his visit, and presented him with a book he had written (one presumes the Treatise). Michell also mentioned a theory which impressed Boscovich enormously, and this was probably the theory of "molecular magnets" which Boscovich described in greater detail in his next letter of 20 November.[40]

In this letter he resumed his account of his Cambridge visit and gave what appears to be an expanded account of the meeting briefly mentioned in the earlier letter. He described the principle magnetic experiment shown him by Michell, and then outlined the theory which Michell derived from it.

The experiment involved the production of magnetism in a piece of soft iron by the action of the magnetic needle of a compass. Michell placed a compass with a magnetic needle on a table, and held over it a thick two foot long bar of soft iron, firstly aligned with the magnetic axis, and with the top close to the needle, which reversed the direction of the needle; and next with the bar the other way around, which produced another reversal. When he held the bar perpendicular to the axis it did not create any sensible motion in the needle; and holding it thus he brought it near to the needle as the square of the cosine of the angle made by the rod with the axis. Boscovich did not say what the effect of this action was.

He next explained Michell's theory of magnetization according to which the iron attracted the magnet only because it had itself become magnetic through the action of the magnet. A small piece of iron became strongly magnetic in this way, whereas a larger piece of very soft iron received little magnetic strength from the magnet. The ultimate reason for the iron's becoming magnetic, Michell believed, was the connection it achieved with the earth, whereby it acquired the two magnetic poles.

According to Boscovich, Michell believed that iron possessed a great quantity of very small magnetic particles, each possessing two points corresponding to the poles of a magnet. Michell had referred in the Treatise to the poles of a magnet as point-sources and had spoken of the possibility of their being brought together as close as one wished,[41] and these magnetic particles (Markovic's "molecular magnets"), appear to have been the logical conclusion of that idea.

In each of Michell's particles one "point" or "end" attracted one of the points of another particle in duplicate inverse ratio

of the distance between them, and repelled the other point of the other particle according to the same ratio. The opposite point of the first particle respectively repelled and attracted the two points of the second particle. Thus far Michell seems to have based his description of the "molecular magnets" on his theory of magnetism in the Treatise.

Each point of the first particle had an action on each point of the second Boscovich said, and Michell took the difference between the two separate actions of the two points of the first particle on one end of the other, finding the net prevailing action to be in triple inverse ratio of the distances. The net prevailing action of the first particle on the second was as the quadruple inverse ratio of the distances. Here, it seems to me, Michell took into account the implications of the bi-polar nature of the action of any magnet on another magnet, a question not discussed in the Treatise. The ratios for the interaction of the magnetic particles were perhaps extrapolations from experimental determinations of the action of the poles of the magnets on each other; and imply the recognition that each point of a magnetic particle has a two-fold impact on another magnetic particle, as had each pole of a magnet on another magnet.

Boscovich next outlined the theory of magnetization which Michell derived from this theory of magnetic particles, as follows. Michell thought magnetization to be the result of the alignment of iron particles in a body; magnetism was produced in a body when many of the iron particles were turned in the same direction. The magnetic power could be easily gained and easily lost in soft iron, while hard-tempered iron or steel did not gain it as easily but retained what magnetic power it received. In the Treatise Michell had noted that harder steel received magnetism with greater

difficulty than did iron or soft steel, but retained it more effectively;[42] and his theory of magnetization explained that fact.

Although Boscovich did not elaborate on this theory of magnetization by particle alignment, one can gain further insights into Michell's reasoning from Boscovich's account and the Treatise, and a tentative explanation can be put forward. It seems to me that Michell thought that particles in harder substances were locked more rigidly into place, producing greater resistance to penetration; thus the harder a bar of iron or steel, the more tightly held in position would be the iron particles.

The action of a magnet on iron particles was presumably analogous to the action of a magnet on a piece of iron: a magnet could attract a piece of iron and render it magnetic by polarizing it. In a similar fashion a magnet attracted the iron particles in a bar and polarized and then aligned them by the interaction of the poles of the magnet with the newly induced poles of the particles. If, as Boscovich implied, Michell thought the particles of iron naturally possessed two magnetic poles, then the initial polarization would not be required; or alternatively, if the particles possessed some type of non-magnetic polarity, the initial result of the magnet's action would be to induce magnetic polarity in those poles.

In whatever manner the particles of iron achieved magnetic polarity, the magnetization of the piece of iron or steel required the alignment of these particles in the same position. One would infer from Michell's remarks in the Treatise about magnetic poles as points, and about the magnets being theoretically divisible into any number of parallel section magnets,[43] that this meant the north-south alignment of the particles with respect to the

magnetic axis. The mere common alignment of the axes of the particles would not be sufficient; indeed the magnetization of the particles presumed their alignment along the magnetic axis. However, once the particles were magnetic, they could be affected by other magnets or magnetic particles, and hence presumably "damaged" by having their power lessened or their poles reversed, as was the case with magnets. If the magnetic particles in a magnet were all aligned with the magnetic axis, the result would be the harmonious interaction of the polar powers of the individual particles, and this perhaps increased the stability and resistance of the magnet to damage by the interaction of the powers of the particles, above what resistance they already possessed because of the hardness of the iron or steel.

The magnetization and alignment of the partioles produced a cumulative effect in the iron or steel, which generated the magnetic power of the body as a whole, though Boscovich's account did not say how Michell explained the relation between the magnetic power of the particles and of the magnet. Nor did the account indicate how magnetic power appeared to come from a point-source pole of a magnet, as Michell had insisted in the Treatise. One may speculate that the magnetic power of the magnet was the result of some combination of the power of the individual particles, which themselves obeyed the inverse square law for their simplest interactions.

Michell's theory of particulate action to explain magnetization does offer some clues as to the nature of the "resistance" to damage which he claimed in the Treatise that a magnet possessed. This resistance was directly dependent on the hardness of the iron or steel and was the measure of the power that a magnet could receive; if it received more, damage would result if that excess power were not expelled.[44] He had also mentioned that in harder

steel the two actual point-source poles of a magnet were closer to the ends of the magnet than was the case in magnets of softer steel. Thus he seems to have implied some connection between the hardness and resistance of the steel and the location of the actual magnetic poles. Perhaps the very distance of the two poles from each other in the harder magnets increased the resistance to damage by making them less liable to interference with each other when other magnets acted upon them. This may have been a result of the poles of the constituent particles themselves being farther apart in harder magnets, which with the operation of an inverse square law of decrease over distance would make them less liable to mutual interference.

The theory of particle action would also help to explain how a magnet's resistance to damage would produce the expulsion of excess magnetic power. If the induction of magnetic power was simply the alignment of the particles along the magnetic axis of a piece of iron or steel, the presence of more magnetic power than it could receive was simply the presence of more magnetic power than was needed to produce the magnetic alignment. Michell had indicated in the Treatise that a very strong magnetic pole acting on a weaker like pole could either lessen the magnetic strength of the latter, or reverse its polarity.[45] The particle theory would explain these respectively by the moving out of alignment of some or all of the particles so that their magnetic strength and that of the magnet as a whole were lessened, and by the reversal of the poles of the magnetic particles. The harder the steel of the magnet, the greater its resistance to such damage, for the particles were then less likely to be moved or reversed in polarity by the activity of a stronger magnetic power. Thus the resistance of a magnet, as Michell implied in the Treatise,

was a power, namely the power of the iron particles of a body to resist the influence of another magnetic source; and in bodies without iron particles that resistance was non-existent because a magnet could not attract, let alone magnetize, a body without particles capable of being influenced by and resisting magnetism.

There was implicit in this theory a concept of the interaction of iron particles not only within a piece of iron or steel, but between a magnet and the iron particles of another body. A magnet initially polarized and then attracted a non-magnetical body containing iron particles, and this suggests that the iron in the magnet actually attracted iron particles in the other body. We have seen that Michell argued that a magnet attracted a body by first rendering it magnetical, so that clearly he thought the magnetic attraction between iron particles described in his theory of "molecular magnets" took place after magnetization occurred. Iron particles already magnetized would first polarize and then attract iron particles, for attraction could only take place when there were unlike poles which could attract each other. Michell did not explain how an unpolarized iron particle came to possess poles; nor is it clear that he did suppose a non-polarized iron particle to exist. It is perhaps conceivable that he regarded iron particles as possessing in some manner balanced attractive and repulsive powers which the process of magnetization transformed into polarized points, which would be a process analogous to the transformation of an iron bar into a magnet with two poles. Certainly for the latter process to occur the presence of iron particles was necessary, and perhaps Michell supposed iron particles to possess a balanced neutrality of powers, which the presence of a magnetic source could alter and polarize. In this case, the strong resistance to influence and damage which magnetic particles

possessed was perhaps for Michell a result of this polarization and the concomitant emergence of magnetic powers in the particles themselves. Thus when the potential magnetic polarity had been realized, the particle became itself a source of magnetic power, and its resistance to the further influence of strong magnetic powers, though not absolute, was such that it could have its strength diminished or its poles reversed without losing its magnetic polarity.

Boscovich concluded his description of Michell's theory with the remark that it explained phenomena without the use of fluids or vortices. We can also note that the theory maintained from the Newtonian canon the concept of point-sources radiating powers outwards according to some given ratio. It is unclear whether or not Michell regarded the attractive and repulsive points of magnetic particles as consisting of anything more than the actual attractive and repulsive powers, and thus one cannot say whether he thought of the points as being those powers, or as merely possessing them. He later maintained a neo-Lockean position that a substance was nothing more than its properties and powers;[46] but there is no indication of his thoughts in 1760 on this question and it is thus impossible to say whether or not he regarded powers as a property somehow added to a point, in the same manner as Newton and Locke had ascribed properties to particles of matter.

Michell's basic concept of magnetic particles consisting of points of attractive and repulsive powers acting on each other and on other particles explained magnetism very simply in terms of inter-particulate action. The theory was as simple in stucture and as revolutionary in its implications as Boscovich's own theory of point-atomism. Its development may well have followed in time the emergence of Boscovich's theory, the latter having published his first mention of it in 1745; yet it seems to have been inde-

pendent of Boscovich's. The fact that Boscovich took the time and trouble to listen to Michell's account, to observe his experiments, and to write to his brother of the theory, and particularly in such favourable terms, suggests that Boscovich did not regard it in any way as derived from his own theory.

Boscovich's account poses one difficult problem in the chronology and independence of Michell's theory of matter, however, and Priestley's description of Michell's theory of penetrability of matter in his History of Optics of 1772 does not resolve it.[47] Priestley implied there that Michell accepted the mutual penetrability of particles of matter consisting solely of powers.[48] Yet Boscovich observed in 1760 that Michell said that he had long believed immediate contact never occurred, being impeded by strong repulsive powers, and that he had come to this conclusion without knowing of Boscovich's theory; Boscovich added that Michell did not prove it in the way that he himself did. We have seen that Boscovich regarded Michell's theory highly, and thought it to be independent of his own, and this last remark suggests that he thought Michell had reached the same conclusion as he on the subject of immediate contact, namely that strong repulsive powers made it impossible.

Michell's theory of magnetic particles did not however deal directly with the topic of immediate contact, though it did suppose the existence of both attractive and repulsive magnetic powers in points of the same particle. Michell had said in the Treatise that the point-source poles of an artificial magnet could be made as close as one pleased,[49] and I have argued that the theory of magnetic particles took the notion to its logical conclusion by drawing the point-source poles together in one particle. He had also maintained that harder magnets had poles farther apart, as well as greater resistance to magnetic power, and were thus able to

beoome stronger. As the resistance deoreased the poles moved closer together, and one ould perhaps speak in theory of bodies with no magnetio resistance having non-existent magnetio poles oo-extensive with each other at the centre of the body. Extrapolating from a body to a partiole one ould oonoeive of a non-magnetized iron partiole as oonsisting of potential powers of attraotion and repulsion in the form of co-extensive (non-existent) attraotive and repulsive points. The partiole would beoome magnetio by the differentiation of the attraotive and repulsive powers whioh would then make themselves manifest in the form of points. Such points would presumably only gain and maintain their separate identity because some repulsive power, perhaps the power of another magnet, separated them and prevented their fusion, though immediate contact between the two would be conceivable because their opposite polarity would produce an attraotion. If this reasoning has any validity, perhaps Michell thought both immediate contact and mutual penetration possible for the points of a magnetic partiole, despite the existence of strong repulsive powers.

Boscovich said in his Theory that infinitely strong repulsive powers prevented immediate oontaot and mutual penetration of point-atoms; and he also noted that mathematioal point-atoms would not be oapable of oontaot but only of mutual penetration if those repulsive powers did not exist, for a mathematioal point has no parts and cannot touoh another point though oapable in theory of oocupying the same position.[50] Even this last occurrence Boscovich regarded as infinitely improbable, for there was an infinitely small likelihood that any two points would oome to occupy the same position in the universe.

Acoording to Priestley's discussion in the History of Optios of Michell's ideas on optics and matter, Michell was oonvinced by

the time of writing (about 1770)[51] that the repulsive powers of matter were not infinitely strong; and Priestley implied that he had arrived at this concept (penetrability) before the meeting which we know took place in 1760. As I have indicated, Michell's theory of magnetic particles did not deal with immediate contact or mutual penetration of particles, though the manner in which the theory appears to answer questions about magnetism and magnetization left unanswered in the Treatise suggests that the theory of magnetic particles was the first major stage in his development of a theory of penetrable matter consisting only of powers, a theory based on a principle, the denial of which was one of the fundamental axioms of the theory of Roger Boscovich.

CHAPTER THREE

MICHELL'S IDEAS ON LIGHT AND ON THE POWERS AND PENETRABILITY OF MATTER

(1)

Michell became interested in astronomy during his years at Cambridge, and in 1760 he published in the Philosophical Transactions a brief description of his observations on the comet of January 1760.[1] He published nothing more on the subject while at Cambridge, and it was not until 1767, three years after he had left the university, that there appeared in the Philosophical Transactions his first major astronomical paper, "An Inquiry into the probable

Parallax, and Magnitude of the fixed Stars, from the Quantity of Light which they afford us, and the particular Circumstances of their Situation."[2]

This paper is best known for its use of probabilistic arguments to show that the stars in the universe are not distributed randomly, but according to some as yet unknown "appointment" or law of the Creator.[3] On this basis Michell argued that stars which appear to be grouped in pairs, clusters or systems may in fact be linked by some force or power operating there. The paper contains an appendix on the twinkling of the fixed stars,[4] which gives some hint of the ideas on light and perception which underlay Michell's apparently simple assumption of the particulate nature of light.

Michell used the argument put forward by Pierre Bouguer in the latter's posthumously published Traité d'Optique of 1760, a work he cited several times in the paper, that an observer can distinguish differences in brightness between two objects of as little as one part in sixty-six.[5] This observation suggested to Michell that the organs which received the impression of light, and the brain which interpreted these impressions, were very sensitive indeed to be able to detect so small a difference. From Bouguer's conclusions he was led to think that the arrival at the eye of three or four particles of light from a point-source in a second could be enough to render such a transmitting source visible. He thought that the arrival of these discrete particles in rapid succession could create the constant perception of a visible source because the perception lasted slightly longer than the actual event of the impression. A star appearing to be a mathematical point could be rendered visible by the arrival at the eye of three or four particles per second, while for larger stars more particles would produce the same effect. For a star as bright as Sirius Michell estimated

the number of partioles necessary to create a oonstant perception to be no more than three or four thousand per second.

The logical struoture underlying Miohell's argument is interesting, for he seems to have been oonoerned to explain the oonstant perception of a light source, and the theory of particle emission apparently seemed to him the most reasonable way of doing this. Having assumed that light was particulate and was capable of produoing an impression on the eye, the problem was then one of determining how many partioles were necessary to render the source oonstantly visible. The duration of peroeption of light from a point-source oould be experimentally determined and the figure thus obtained would indicate how many partioles per seoond were required to render that source visible, and one may speculate that Miohell's reasoning ran thus, though he did not desoribe this part of his deduction.

He next applied this theory to explain the twinkling of the fixed stars, noting that a fluotuation in the amount of light reaching the eye from a star aooompanied the twinkling phenomenon.[6] This apparent inorease and decrease oocurred fairly regularly, perhaps as often as four of five times per second. This was possibly the result, he argued, of suocessive partioles of light from a single source ooming in slightly greater or lesser numbers, a ohance ocourrence made possible by the very small number of partioles entering the eye in a quarter or fifth of a seoond. If a single partiole could be perceived, and if one hundred partioles entered the eye eaoh second from a second magnitude star, a slight ohange in the number of particles per second might be notioeable, and if on average twenty particles entered the eye every fifth of a second, the addition of one or two partioles in any given interval of a fifth of a second, and a conoomitant subtraotion of one or two

particles from the next equal interval of time, could produce a noticeable fluctuation in brightness, and hence produce the appearance of twinkling.

Michell pursued somewhat farther the implications of these possible chance inequalities in the number of particles entering the eye every second, observing that one could argue that a star as bright as Sirius emitted too much light to permit chance inequalities large and frequent enough to produce the necessary fluctuations. He admitted the possibility of this being the case, but added that no determination of the validity of this position could be made until more was known about how variable was the amount of light needed to create the twinkling effect.

Michell did not discuss the theory of light emission underlying this theory, but he clearly regarded light as particulate, and he assumed a constant average rate of emission from stellar sources. He did not however offer any explanation as to why chance inequalities in the amount of light would be perceivable by an observer, though the argument seemed to imply chance variation in the rate of emission. Although he implied that such variations took place within narrow and fairly well defined numerical limits, and though negative and positive variations seemed to cancel each other to produce a constant average rate of emission, there is an element of randomness suggested which he did not try to explain.

In the body of the paper Michell had sought to show that the apparently random distribution of the stars was in fact not arbitrary or random, but governed by laws of nature ordained by God. In his discussion of the twinkling of the fixed stars he seemed to posit an apparently random occurrence, and made no attempt to explain by any law or theory this apparently arbitrary fluctuation in the rate of emission.

The theory of perception implied in the appendix to the paper was simple and undetailed. Light particles made an impression on the "organs of sight" and these impressions were transmitted along the optic nerve to the brain, where they became perceptions. This mechanical theory of perception was neither original nor unique; indeed it was consistent with Newton's Opticks, as was the particle-emission theory of light which Michell advanced. In common with both Locke and Newton's theories of perception, Michell's notions implied an active role for light whereby particles of light impressed themselves upon the eye, triggering a series of events in the nerves and brain which produced a mental perception. Michell did not describe how the light particles were able to make an impression on the eye, nor how the eye received the impression; but his continuing research as described in Priestley's History of Optics was to produce a theory of light which helped to explain these phenomena, as will be seen in the remainder of this chapter.

(11)

In 1767 Michell moved from the rectory of Havant, Hampshire, where he had served from 1765, to that of Thornhill, near Leeds. Joseph Priestley became minister of Mill Hill unitarian chapel in Leeds in 1767, and in early 1768 wrote to John Canton that he was seeing John Michell "pretty often".[7] Thus began the friendship and co-operation which led to Priestley's publication of the

History of Optics in 1772.

In the History Priestley described Michell's ideas on the emission, momentum and transmission of light, and the "doctrine of attractions and repulsions" Michell used to explain these phenomena. Priestley's description is the principle first hand account of Michell's theory of light, and this, and Michell's 1767 and 1784 astronomical papers constitute the primary sources on this subject. Priestley's account appears to have been based on long and detailed discussions with Michell; and Michell's close collaboration in the preparation of the History which apparently included proof-reading the work,[8] suggests that he approved of Priestley's desire to describe his work and agreed with Priestley's account and the use to which Priestley put it in the defence of a materialist and corpuscular theory of light.

Michell ascribed a very strong repulsive power to particles of matter, and much of Priestley's account concerned Michell's attempts to determine the nature and strength of this repulsive power. He described Michell's experiment to determine whether light particles possessed momentum, his calculation of the strength of the repulsive power responsible for the emission of light from the sun and their resulting momentum, and his explanation of the interaction of attractive and repulsive powers at the surfaces of bodies which determined the reflection or the transmission of light. A more detailed analysis of this work and its implications than has been done before may be able to show the comprehensive nature of Michell's theory of light,[9] and its connection with his theory of magnetic particles, his concept of the penetrability of matter, and his more general theory of matter as a manifestation of attractive and repulsive powers.

Unfortunately Priestley gave no information as to the dates

at which Michell carried out these various researches. He said that Michell developed his theory of the penetrability of matter before he had even heard of Boscovich;[10] but although Michell's theory of penetrability was closely linked to his theory of light and his doctrine of attraction and repulsion, its origins, as Priestley indicated in the History[11] were to a great extent in Michell's philosophical speculations concerning the nature of matter and "spirit" which will be discussed later in this chapter. Michell's work on the ability of light to penetrate matter was perhaps an illustration or even a confirmation of the theory of penetrability, and as such may have followed the development of that theory, though in the absence of a definite date for the latter the dating of the work on light is still very difficult.

The 1767 paper was vague on the theory of emission and perception and although nothing in it contradicted the ideas about to be discussed here, the simplicity of the account of those subjects in that paper suggests that Michell was either unwilling at that time to "unravel" his "abstruse" ideas on the subject, or else that he was still developing the theory which Priestley described in the History. The only clue which Priestley contributes is his reference to Michell's having attempted the experimental determination of of the momentum of light "some years ago",[12] an inadequate basis on which to attempt to date the various pieces of research which he described. Thus the discussion of the connection between the separate items of research and the attempt to reconstruct from Priestley's brief but invaluable account the nature of Michell's theory of light must be done without definite dates being assigned to Michell's work, except for noting that the theory of penetrability was perhaps developed before 1760, as suggested in the previous chapter.

Firstly, let us examine Priestley's description of Michell's work on the momentum of light. According to Priestley Michell decided to improve upon various attempts to ascertain experimentally the momentum of light. Homberg had ascribed to light rays an ability to move light substances and to increase the speed of motion of a small lever, an effect which Priestley said Mairan later attributed to the heating of the air.[13] Mairan also attributed the motion of his own experimental instrument, a small windmill-like object, to the heating of the air.

Michell was apparently dissatisfied with this conclusion and decided, in Priestley's words,

> ...to ascertain the momentum of light in a much more accurate manner than those in which M. Homberg and M. Mairan had attempted it;....[14]

From this statement, and from the fact that Priestley proceeded to apply the quantitative results of the observed momentum, it seems possible that Michell had assumed the momentum of light as a given fact, and was perhaps concerned as much to illustrate it by an experiment and to ascertain its strength as to establish the fact of its existence. Priestley's use of the experiment as a support for the materiality of light perhaps imparted to his account of it a somewhat different emphasis from that initially intended by Michell: as he observed in the History:

> It would certainly go a great way towards proving the materiality of the rays of light, if it could be observed that they had any momentum, so as, by their impulse, to give motion to light bodies.[15]

He carried out the experiment, according to Priestley, "some years ago" using a two-foot concave mirror which he did not have "at his own house,"[16] though Priestley did not say where he located a suitable mirror. He built a small and very light windmill-like instrument, apparently a modification of Mairan's simpler device,

a six-spoked wheel with very small wings, suspended by a magnet; it consisted of a thin plate of copper about one inch square attached to the end of a ten-inch harpsichord wire, to the other end of which was affixed a small "shot corn" as a counterbalance, the whole placed by means of an agate cap on a sharp needle on which it could turn freely. A one-third or one-half inch magnetized sewing needle was fixed horizontally at the centre of the wire, and at right angles to it.

Michell put the instrument upright in a box about one foot long and about six inches deep and wide, with a glass front and lid, and placed the box so the sun's rays entered at right angles to the length. The instrument was aligned in the same direction by a magnet affixed to the box, which could hold the magnetic sewing needle and hence the instrument in any desired position.

Michell now did as Mairan had done, focussing the sun's light by the two-foot mirror, and reflecting the sun's light on to the mirror's focus on the copper-plate. The plate moved about an inch per second until it struck the back of the box, whereupon Michell removed the mirror and the magnet returned the instrument to its original position. He repeated the experiment successfully several times and achieved the same results with the copper-plate at the left instead of the right side of the box.

By this time the sun's heat was warping the copper-plate and fusing it with the wire. The instrument was no longer vertical, and the heated air in the box moved upwards with sufficient force to drive the plate in the opposite direction to the sun's rays "in the same manner as the sail of a windmill...."[17] Michell stopped the experiment and as he lacked a suitable mirror of his own he did not try it again.

Priestley implied that Michell had been convinced of the

momentum of light by this experiment, as Priestley himself seems to have been.[18] Michell was aware of the problem noted by Mairan that the action of air heated by the sun could cause motion on the part of the instrument, which had led Mairan to attribute the irregular motion imparted to his simpler device to that source, rather than to any momentum of the light particles themselves. As we have seen, Michell was aware of the motion of the heated air in the box, and found that it produced an effect counter to that initially produced when light was focussed on the copperplate. One may speculate that Michell perhaps found in the fact that the heated air produced a contrary motion a further confirmation of the effect of the light in the first few attempts. It is not certain whether Michell was testing the theory experimentally, or whether he undertook the experiment with that theory as an assumption;[19] nor is it at all certain that the existence of momentum could decide between the corpuscular and wave theories.

Michell's friend Gowin Knight had argued in his 1748 Attempt that the momentum of light would be the same whether one assumed emission of particles or vibrations of an aether in explaining light:

> It makes no Difference, in respect to the Action of a Body impinging upon another, whether the impinging Body has already moved through a great Space, or is only just put in Motion, provided the Velocity and Direction be exactly the same in both Cases. Therefore a Particle of Light will strike upon the Retina of the Eye with the very same Effect, when it receives its Motion from the next contiguous Particle, as when it has moved all the Way from the Sun, with the same Direction and Velocity.[20]

For Knight momentum was not a decisive issue for the wave-particle debate. His argument does however suggest another important reason for the assumption of light's momentum: the necessity of such momentum if light is to cause perception in the observer by the actual impressing of the eye. Knight seems to have assumed momentum

to be a necessary assumption for a sensationalist view of perception, just as Michell appeared to do in his explanation of the twinkling of the fixed stars, and as we shall see presently, in his "doctrine of attractions and repulsions."

Another major part of Michell's work on the momentum of light was his calculation of the force by which the sun imparted momentum to particles of light at emission, described by Priestley in an appendix to the History.[21]

Michell's calculation seems completely independent of his experiment on momentum in the sense that it was a mathematical and rational deduction based on several Newtonian propositions and not readily verifiable by an experiment such as the one on momentum. Michell calculated the time required for a particle at the sun's surface to revolve around the sun, which figure also represented a mean proportional between the sun's diameter and the distance a body impelled by the sun's gravity would fall in one second. The ratio between the accelerations caused by the sun's and the earth's gravity he found to be 448 to $16\frac{1}{2}$.[22]

Michell next turned to Proposition 39 of Book I of the Principia in which Newton calculated the velocity of a body moving in a straight line at right angles to another body.[23] One implication of the proposition was that the velocity of a body falling under the impulse of gravity from an infinite height to any given height equalled the velocity acquired in falling the remaining distance. Thus, Michell argued, the velocity of a body fallen from an infinite height to the sun's surface was equal to the velocity it would have acquired in falling from the surface to the centre. He thereby calculated the velocity acquired in falling from an infinite height, which was approximately one 497th part of the velocity of light; the ratio of the force producing the velocity of light to the

force producing the last mentioned force being as the square of these velocities, namely as 247,009 to one.

Thus the diminution in the velocity of light caused by the sun's gravitation was very small, equalling one 492,032nd part of the original velocity, and virtually all of this diminution occurred before the sun's light reached the earth. The effect on particles of light of the gravitational force of a body as large as the sun was thus very small when compared with the enormous momentum imparted to the light at the time of emission.

Michell next sought to compute the force of propulsion responsible for this enormous momentum by determining the ratio between the propelling force and the force of gravity on earth. Assuming the repulsive power at the surface of the sun to act uniformly through the distance of one-hundredth of an inch, he calculated the ratio of this force to the force of gravity at the earth's surface, and found the former to be 1.9×10^{19} times greater than the force of the earth's gravity. This figure also represented the momentum imparted to a particle of light by the sun's repulsive power.

Michell reasoned that the force required to stop a particle possessing this momentum must be equal to the force which produced this momentum. The forces which altered the direction or velocity of a particle of light when it impinged on a surface could accordingly be seen to be very great, and reflection therefore required a force even greater than that responsible for propulsion. Michell estimated that the repulsive power of the surface of a medium producing reflection was probably exerted within a distance of about one seventy-thousandth or one eighty-thousandth of an inch.

In this manner Michell determined the strength of the forces responsible for the projection of light from the sun and for the refraction and reflection of light at the surfaces of bodies. The

geometrical and deductive nature of his reasoning showed the enormous influence of Newton, and yet the implications of Michell's argument were central to his theory of matter which rejected the solidity and impenetrability of Newtonian corpuscular philosophy. Michell's theory of matter, as we shall see, attributed all the phenomena in nature, as well as our perception of them, to the activity of attractive and repulsive powers, and even particles themselves became for him nothing more than the manifestation of very strong but finite powers.

Michell's deductive reasoning concerning the emission and momentum of light was not proof of a corpuscular theory of light, for the particulate nature of light was one of the basic postulates of that reasoning. It is evident from observation that light could penetrate transparent substances, and Michell assumed that it was able to do so because of its momentum. He was aware of the enormous velocity of light, and reasoned that a repulsive force gave it this velocity and endued it with very great momentum. He assumed the existence of particles possessing such a momentum, and the reasoning whereby he calculated the strength of the repulsive power producing light's emission, velocity and momentum was a deduction from this premiss.

Michell related the momentum of light to the phenomenon of emission, arguing that a very strong power of repulsion must be the cause of emission at such high velocity and with such enormous momentum. Powers of the same order of magnitude must be responsible for the reflection of light, he argued, and the elaboration of this hypothesis can be seen in his "doctrine of attractions and repulsions", the subject of the next section.

(111)

Michell proposed explaining the colours of thin plates and Newton's alternate fits of easy reflection and easy transmission of light particles by the action of attractive and repulsive powers and vibrations of the surfaces of substances. His theory as described by Priestley involved the interaction of the powers of light particles and the powers and vibrations of the reflecting or transmitting substance.[24] This "doctrine of attractions and repulsions", as Priestley called it, combined easily with the theory of transmission discussed in the previous section.

Newton had explained the colours of thin plates in terms of alternate fits of easy reflection and easy transmission. Proposition XII of Book Two, part III of the Opticks stated:

> Every Ray of Light in its passage through any refracting Surface is put into a certain transient Constitution or State, which in the progress of the Ray returns at equal Intervals, and disposes the Ray at every return to be easily transmitted through the next refracting Surface, and between the returns to be easily reflected by it.[25]

Reflection or refraction was determined at the second surface of a thin plate, and depended on the distance between the two surfaces, because the disposition of the first surface which was somehow communicated to the second, also influenced this determination. The nature of this disposition was uncertain:

> ...Whether it consists in a circulating or a vibrating motion motion of the Ray, or of the Medium, or something else, I do not here enquire.[26]

The periods in which either disposition existed, Newton called fits of easy reflection and easy transmission, and the periods between these two were the intervals of the fits. Light was in fits before reaching the body,

> And probably it is put into such fits at its first emission from luminous Bodies, and continues in them during all its progress.[27]

A surface which refracted most strongly if rays were in refractive fits, reflected most strongly when rays were in fits of reflection (Book Two, Part III, Proposition XIV). This was so because reflection was caused by some power which the solid parts exerted on light rays at a distance (Book Two, Part III, Proposition VIII); and because reflection and refraction were caused by the same power (Book Two, Part III, Proposition IX).

Boscovich supposed in the Theory that the fits resulted from the unequal propulsion imparted to the various parts of a light particle, believing as he did that light particles consisted of point-atoms or "puncta".[28] Priestley described Boscovich's theory of the fits thus:[29] Boscovich thought that the intervals of the fits would differ in different rays because differently refrangible rays would be affected at different stages in their motion after refraction as a result of their different velocities; because inequality of action of the points of a particle would cause different actions on the part of the particle at the time of reflection or refraction; and because a transparent body would act on rays according to the different angles at which they entered the body because of the varying dispositions of their parts with respect to the surface.

After outlining the theories of the two men, Priestley discussed objections to them, apparently on the basis of Michell's ideas, for at the end of the discussion he noted:

> My objections to Newton's manner of accounting for the colours of thin plates are of long standing, but the hint of accounting for them in the manner that I have attempted to do, by the doctrine of attractions and repulsions, was first suggested to me by Mr. Michell....[30]

Priestley's first paragraph concerned vibratory motions in the surface of the plates, while the second explained the fits by the operation of attractive and repulsive powers at the surfaces of

the plates.

Priestley stated the principal objection to light rays being set in vibration at the time of their emission from the luminous body, namely: it was unlikely that anything as small as a particle of sunlight (in Boscovich's theory consisting of mathematical point-atoms) could be propelled with unequal forces at work on its various parts when those parts were (to Priestley's mind) so very close together. Priestley thought Boscovich's particles of light to be infinitely small,[31] whereas they contained point-atoms and were not themselves infinitely small.

Priestley's rejection of Boscovich's position says nothing about the implications of the theory he was describing for the polarity of light particles posited by Newton, who had described polarity as

> ...a Virtue or Disposition in those Sides of the Rays, which answers to, and sympathizes with that Virtue or Disposition of the [Island] Crystal, as the Poles of two Magnets answer to one another.[32]

Bosocvich had posited light particles consisting of point-atoms which could move with respect to one another, but this was not a polar situation in Newton's sense, for no difference in polarity among the different point-atoms was assumed. On the other hand Michell's magnetic particles consisted of polarized points and although there is no specific mention of Michell's modelling his conception of light particles on his earlier idea of magnetic particles, the remainder of Priestley's account makes this possible.

Light rays were most probably emitted "with an uniform disposition,"[33] and their reflection or refraction was determined by the bodies they reached. Minute vibrations of "small parts of the surfaces of the mediums" determined whether particles were reflected or transmitted, such vibratory motions seeming to Priestley

very likely, though their source unclear. He did not mention Newton's proposal that light particles might create such vibrations in the surfaces of any medium they reached,[34] though Michell's theory which he was describing seems to have taken this idea into account.

The vibrations were "independent of action and reaction" between the transparent bodies and impinging particles of light, "though, probably, excited by the action of preceding rays;"[35] they were already in existence, perhaps, one imagines, initiated by a bombardment of light rays, and because they occurred in "small parts of the surfaces" rather than in individual particles, they were not affected by the impact of any single particle.

Priestley admitted his own uncertainty on the subject of the alternate fits by conceding that Boscovich might have been partially correct in his assumption of some predisposition of light to be either transmitted or reflected, and he accordingly proposed that some combination of this predisposition and the vibration of the parts of the surface might cause the alternate fits. This compromise solution brings to mind an alternative which he did not mention, though his description of Michell's theory implies it: a predisposition of light to be reflected or transmitted, and a predisposition of the surface parts to reflect or transmit. This would assume a polarity both of particles and surface parts, and Priestley did not discuss polarity explicitly in this account of Michell's theory. Yet despite his contention that particles of light were too small to have their constituent parts affected differently by the powers causing their emission from a luminous body, Priestley did not deny the posibility of light being polar in nature, and Michell's explanation of the fits utilized a polar theory, just as had his theory of magnetic particles.

The seoond paragraph of Priestley's acoount described a polar theory of easy fits, presumably based on Miohell's "doctrine of attraotions and repulsions", and explaining the oolours of thin plates acoording to the theory

> ...that every partiole of the medium has a great number of equal alternate intervals of attraotion and repulsion, relatively to the partioles of light, but that these intervals are of different magnitudes, acgording as the partioles of light are of different oolours.[36]

Miohell apparently thought that as the refraoting medium was a material body, every one of its particles had intervals of attraction and repulsion towards (material) partioles of light. These intervals were very numerous and apparently of a temporal rather than a spatial nature, for the sentence just quoted and the one whioh followed where Priestley spoke of the "ooinoidence" of intervals at different surfaces of the medium, make it appear that Miohell assumed a temporal alternation of attraotion and repulsion. Only this interpretation seems to make sense of the term "interval", because a spatial interpretation assuming alternate spheres or layers of attraotion and repulsion does not make sense of the term "coincidence". One is here speaking of a partiole moving with a velooity so great that its passage through a thin plate oould be regarded as instantaneous; but alternations of attraction and repulsion oould ocour in both partioles and parts of the medium when the polar powers of each came into oontact with the polar powers of the other. Thus "equal alternate intervals of attraction and repulsion" were presumably equal and very brief successive periods in which the surfaces of a medium either attracted and transmitted, or repelled and reflected, partioles of light of any given oolour.

Miohell's theory explained the relationship between the thickness of a thin plate and its reflection of a oolour in these

terms:

> Now if the thickness of any transparent medium in which the particles of matter are uniformly placed, is such, that the attracting intervals of the extreme particles, as well as the repelling intervals, coincide with one another, i.e. attracting with attracting, and repelling with repelling, in regard to any one kind of rays, as the red for instance, by the united force of these extremes (all the intermediate particles of the medium mutually destroying each others effects) these rays will be reflected.[37]

Newton maintained that homogeneity of particle structure was the cause of transparency in a body, and Michell was evidently aware of this concept, for he thought that reflection occurred in a thin transparent body when the attracting and repelling intervals of the outer surfaces (attracting or repelling with respect to the particles of light) coincided, producing first a strong attraction of the particle followed by a strong repulsion producing reflection. Michell clearly regarded the surfaces of the medium rather than the constituent particles of the surface as the deciding factor.

Robert Smith in his 1738 System of Opticks had advanced a theory of surface powers to explain the penetrability of matter, and Michell was familiar with this work.[38] Smith argued that the action of the power of a surface on impinging light was uniform "in every point of a plane drawn parallel to the refracting surface ...."[39] He maintained that the strength would differ for each successive contiguous plane till the powers reached a termination at some distance on either side of the original surface plane.[40] These two outer planes defined the limits of the "space of activity"; and once a light particle had passed beyond the inner limit of the sphere of activity and into the medium it

> ...will then proceed straight forward; for being attracted or impelled every way alike, or else not at all if it be in empty space, it will have the same freedom of motion in both cases....[41]

This explanation of the role played by the surface powers

of a medium in effecting the refraction of light perhaps influenced Michell's theory of the alternate fits. Michell's theory concerned the "extreme particles" of the medium, presumably a reference to the surfaces of the medium, and the decisive factor for reflection was the "united force of these extremes", namely of the two surfaces. Michell's idea of "all the intermediate particles of the medium mutually destroying each others effects" appears identical with Smith's proposal that a particle would move straight forward once into a medium because of the fact that it was "attracted or impelled every way alike."

For Michell reflection appears to have been caused by the synchronization of attracting and repelling powers of the two surfaces of a thin plate. Such a coincidence of attracting and repelling intervals required the coincidence of like polar attractions with respect to light particles at each surface. This only occurred with respect to the particles of any given colour at certain thicknesses of the thin plate, according to his theory. The powers of the two separate surfaces could interfere with each other because they were so close together and because the powers extended a distance, though small, from the surface.[42] Thus a coincidence of intervals of attraction and repulsion with respect to the particles of a certain colour produced a very strong effect leading to reflection. This balancing and coordination of powers and of intervals of interaction with respect to a given colour took place only at certain thicknesses of the plates where the powers complemented rather than interfered with each other.

Intermediate thicknesses did not produce reflection because

> ...the attracting intervals will coincide with the repelling ones, and the repelling ones with the attracting ones, and these mutually destroying one anothers effects, these rays will pass on freely, and be transmitted.[43]

Transmission was therefore more common than reflection, for it

occurred when the powers of the surfaces did not intermingle in a balanced manner and synchronize with the intervals of the impinging particles. At the intermediate thicknesses the powers interfered with each other and the intervals of attraction and repulsion between the particles and each surface did not coincide. Thus strong attractions and repulsions between the particles and the surfaces did not occur on these occasions and the particles passed through the medium and out of it.

Different thicknesses of plates reflected differently coloured particles, for the intervals of attraction and repulsion with respect to the medium differed according to colour. In his discussion of Michell's theory Priestley spoke of "different magnitudes" of intervals on the part of the medium towards particles of different colours.[44] The simplest explanation of Priestley's statement seems to be that he thought Michell supposed light particles of different colours to have different intervals of attraction and repulsion with respect to the medium. To assume that the particles of the medium possessed different affinities for different colours seems unnecessarily complicated.

It seems simpler to assume that Michell believed particles of light of different colour to possess different intervals and such an assumption would be analogous to Newton's notion that the colour of light particles depended on their size, though going further than Newton's theory in its implication that colour was related to alternations of polarity and to the frequency of such alternations.[45] This interpretation of Priestley's account accords with the suggestion made earlier in this section that Michell's theory of the alternate fits depended on temporal rather than spatial "intervals" of alternation of polarity; and it also makes sense of temporal alternations of polarity of the medium which

then could synchronize or not with the alternations of polarity in the incoming particles and thus produce transmission or reflection.

Since Michell conceived particles of light to be material, one would expect particles of light and the surfaces of a material medium to have similar polar properties. Indeed his work on another type of material particle, the magnetic particle, perhaps indicated how the temporal alternation in the polarity of light could occur. For Michell, the creation or alternation of magnetic polarity in a body was caused by the aligning or re-aligning of the polar "points" of its constituent particles, effected by the movement of the particle, presumably in rotation around its centre. Such particulate motion or "spin" could also have produced a rapid alteration in polarity in quickly moving particles of light which consisted of polar "points".[46] If one supposed with Newton that differently coloured particles were of different sizes a very small resulting difference in period of rotation would be sufficient to explain the different periods of polar alternation for each colour, which seems to have been an essential part of Michell's explanation of the colours of thin plates.

Perhaps Michell believed light particles to be polarized, just as he had supposed magnetic particles to be,(Newton's analogy between magnetism and the polarity of light perhaps suggesting to him such an analogy); and he also thought particles of matter in general to be polarized (as we shall see presently). Thus he probably supposed with Newton a mutual interaction between the particles of light and the medium they reached. This view is consistent with the theory that powers at the surface decide reflection or transmission; indeed it is difficult to imagine how such powers could act on unpolarized particles, for attraction and repulsion

depended on the interaction of polar opposites, as Michell had emphasized in the Treatise on Magnets. In the theory of magnetization outlined to Boscovich in 1760 he had implied that a magnet attracted or repelled by polarizing the object upon which its powers acted. We have seen that Michell attributed the emission and momentum of light to the action of surface powers of the sun, and these could presumably polarize light at the time of emission. If this were the case, perhaps the bombardment of a surface by polarized particles of light could create vibrations in the surface and polarize it by polarizing its constituent particles, analogously to magnetization. Even if this were not the case and light only became polarized under the influence of the powers of the surface upon which it was impinging, it appears that Michell supposed the surface powers of the medium to act upon similar powers in the particles of light.

In summary, Michell explained the colours of thin plates by the supposition that differently coloured light particles possessed different periods of alternating polarity with respect to the surfaces of the medium they reached, the reflection of these particles requiring the coordination of attractive and repulsive intervals between the surfaces and the particles. Reflection of any given colour occurred at certain thicknesses only, where the intervals of attraction and repulsion of the surfaces towards the particles coincided. Michell apparently assumed both the polarity of particles of light, whether caused by emission, or by interaction with the transparent body, and the polarity of "small parts of the surfaces of the medium," presumably resulting in some manner from the polarity of their constituent particles.

Thus the theory Michell advanced concerning the colours of thin plates explained the effect of light on a transparent medium

in terms of the polar powers of the light and the medium. Perhaps utilizing both Newton's analogy between magnetism and light, and Smith's theory of surface powers and the penetration of matter when those powers did not interfere, Michell explained reflection solely with reference to the polar properties of light and of the surface layers of the reflecting medium.

Indeed, his explanation did not presuppose any properties of matter beyond momentum, and powers of attraction and repulsion. These latter powers were apparently located in polar "points" in particles of light, while in a reflecting medium they were the properties of alternate layers or "spaces" of activity at the surfaces of the medium.

There is implicit in Michell's explanation, just as there was in Smith's theory of surface powers, a theory that matter is penetrable because its resistance to penetration is caused by finite powers of attraction and repulsion; and Michell's apparent assumption that light consisted only of polar points provided a means whereby he could explain the properties of light, and matter in general, by referring only to the powers of matter. The penetrability of matter could then be deduced from these more basic properties (the powers of attraction and repulsion), and the momentum of light and its resulting ability to pass through transparent bodies provided the prime example of the manner in which matter could be penetrated.

As we shall see in the next section however, Michell appears to have begun his optical work with a theory of penetrability already formulated from his metaphysical speculations.

(iv)

Penetrabilty, the ability of particles of light to penetrate apparently solid matter, was one of the central concepts in Michell's theory of light, and his theory of matter as described by Priestley in the History of Optics; and Priestley's account indicates that the concept occurred to Michell independently of his work on light and prior to his major optical researches. In chapter two the relation of this concept to Michell's work in magnetism was discussed, and it appeared that his theory of magnetic particles was at least consistent with such an assumption.

Priestley gave very useful information concerning the origin and nature of Michell's concept of penetrability in the History of Optics, and his discussion of Michell's work on light showed the relevance of the concept to his theory of the attractive and repulsive powers of matter. Priestley's brief discussion of penetrability is the only source for Michell's reasoning on the subject, and is both detailed and circumstantial.[47] Priestley later remarked that his rendering of Michell on the matter was as much as possible in the latter's own words, presumably based on their discussions from 1767 or 1768 to 1772. Michell's proof-reading of the text of the History favours the conformity of Priestley's narrative to Michell's recollection.[48]

Priestley described Michell's ideas on penetrability after introducing Boscovich's theory of point-atoms (and of "penetrability" as Priestley termed it) as the easiest way of refuting those who attacked the corpuscular theory of light. He summarised Boscovich thus:[49] Particles of matter consisted of points surrounded by alternate spheres of attraction and repulsion; with sufficient momentum particles could penetrate any body, overcoming the repul-

sive powers of matter which created resistance, and light particles having such momentum could accordingly penetrate material bodies. Priestley's interpretation both simplified and distorted in several important ways Boscovich's theory as we shall see in chapter four where Priestley's use of Boscovich and Michell is discussed in detail.

Priestley emphasized both the similarity and independent development of Michell's and Boscovich's theories. After outlining Boscovich's theory he stated:

> This ingenious hypothesis, at least, one that is the same in every Thing essential, occurred also to my friend Mr. Michell, in a very early period of his life, without his having had any communication with M. Boscovich, or even knowing that there was such a person. These two philosophers had even hit upon the same instances, to confirm and illustrate their hypotheses, especially those relating to contact, light, and colours.[50]

Michell met Boscovich in 1760 and if Priestley's statement was correct (though it was from Michell, an interested party) he had arrived at a theory of penetrability by then.

Michell had conceived his theory of magnetic particles by the time he met Boscovich, though that theory did not necessarily assume penetrability; and he had expressed to Boscovich his belief in the impossibility of immediate contact which suggests his awareness of strong repulsive powers at the surface of bodies. Perhaps this idea led him to think about how the repulsion and resulting resistance to penetration displayed by the surfaces of of bodies might be overcome, though it is not certain that he had pursued this line of reasoning before he met Boscovich. If Michell was convinced in 1760 that the surface powers of repulsion were strong but finite, making immediate contact between bodies very difficult but not impossible, Boscovich may have mistaken Michell's agreement with the difficulty of immediate contact for assent to its impossibility. Michell's 1750 theory of magnetism

had shown that attraction of polar opposites could overcome the repulsive power exerted by one pole of a magnet and perhaps suggested that the repulsive powers at the surfaces of bodies could be overcome. The attitudes of the two men to immediate contact, Michell accepting its possibility and Boscovich denying it in one of the basic postulates of his physical theory, perhaps made misunderstandings on the subject easy, particularly if they discussed the subject only in passing, as Boscovich's account implied. Thus it is possible that Michell had accepted penetrability by 1760, though whether he had applied it to immediate contact and other physical subjects is uncertain.

According to Priestley the occasion for Michell's concept of penetrability was the philosophical and metaphysical speculations of Andrew Baxter (1686-1750):

> This scheme of the immateriality of matter, as it may be called, or rather the mutual penetration of matter, first occurred to Mr. Michell on reading Baxter on the immateriality of the soul.[51]

Baxter had defended the immateriality of the soul and of the powers of nature and the passivity and inertness of matter in his two most important works, namely, An Enquiry into the Human Soul, (1733) and Matho, 2 vols., (1740). He argued that immaterial and penetrable powers activated and surrounded an inert, imperceptible and impenetrable material substance. Matter's passive resistance and impenetrability caused the solidity and vis inertiae of bodies, while the activity of powers such as the attractions of gravitation and of cohesion caused motion and cohesion of bodies in the universe.[52]

Baxter had wondered at the strength of the attraction of cohesion.[53] It was, he reasoned, clearly stronger than the resistance of a body as a whole to motion, and if the resistance of a body or part of a body was effected at its surface, the locus of contact,

it followed that the resistance of the body as a whole was ultimately effected by the surfaces of its least parts, as bodies achieved contact only at their surfaces.

Yet a problem then arose for Baxter concerning this reasoning, for each part of a body was further divisible, so that the attraction of cohesion had to operate on increasingly more minute parts though the strength of the attraction could not be reduced. Baxter observed that some philosophers explained cohesion "by the Presence of superincumbent subtile Matter,"[54] presumably a reference to explanations which utilized an "aether"; but he noted that the complexity and increasing smallness of the particles of a body would take this theory to an absurd result:

> ...there should be more of this <u>other Matter</u>, I think, in the very hardest Bodies, than of their own proper Matter....[55]

Yet surely one can raise the same objection to the immaterial substance with which Baxter himself infused and activated matter, and this appears to me to have been the contradiction which led to Michell's reversal of Baxter's system.

Michell, according to Priestley, understood Baxter to maintain that matter consisted of very small units of matter held together by an immaterial substance. Michell apparently spoke of these units or particles as "bricks" and of the immaterial substance holding them together as "mortar",[56] perhaps a variant on the term cement Baxter used to describe the attraction of gravitation.[57]

The particles or bricks were composed, in Michell's view, of smaller bricks, themselves composed of smaller ones, "and so on ad infinitum". Perhaps Michell had hesitated at this point, thinking about the phenomena observable in nature, for he concluded that bodies generally produced effects by means of the mortar rather than by the bricks. Here Michell began to transform Baxter's

system into one oloser to Looke's oonoept of aotive powers produoing sensations in the observer.[58] Baxter had suggested in his Matho that the mortar so thoroughly covered the bricks as to make them imperceptible.[59] Michell perhaps derived from the writings of these two men the idea that bodies produoed the effect of sensation in an observer by means of this mortar, for the mortar was all one perceived and it was, by Baxter's (and Looke's) reasoning, a power. Michell later extended this oonoept in his Lockean position that all one could know of substance was that it supported properties whioh limited knowledge one gained from the effeots whioh bodies produced.[60]

Baxter's mortar had been immaterial and penetrable, while the brioks were material and impenetrable. Miohell in effect abolished the bricks and thereby simplified the soheme, reasoning that observable phenomena required the existence of "extended and penetrable immaterial substanoe" if one posited impenetrable matter,[61] for bodies possessed extension and required something to activate and hold together matter if one supposed matter to be passive in nature. The immaterial power in Baxter's system rendered matter imperceptible and for Michell this must have seemed true for immediate oontact as well as for visual peroeption. If one conceived the penetrable immaterial power of Baxter as oontaining the repulsive power which inhibited immediate contact, Miohell's reasoning conoerning Baxter's system would lead immediately to the conolusion that this repulsive power was penetrable, and hence not infinite.[62] This became, as we have seen, one of the basic postulates of his optical research.

If impenetrability explained nothing in appearanoes it could be abolished and one could posit instead penetrable material substance, whioh Miohell did. By rejeoting impenetrable matter

one could also abolish immaterial substance, and with the remaining penetrable matter one could explain phenomena without supposing "extended and penetrable immaterial substance", and Michell thus replaced two types of substance (and hence two causes of natural appearances) by one, observable phenomena becoming the effect of penetrable matter alone.

Michell's opinion concerning the properties of substance was described by Priestley:

> ...we know nothing more of the nature of substance, than that it is something which supports properties, which properties may be whatever we please, provided they be not inconsistent with each other, that is, do not imply the absence of each other.[63]

Priestley did not state whence Michell had derived this idea; but the argument echoes Locke's conception in the Essay of substances being the support of properties:

> So that if anyone will examine himself concerning his notion of pure substance in general, he will find he has no other idea of it at all, but only a supposition of he knows not what support of such qualities which are capable of producing simple ideas in us; which qualities are commonly called accidents....The idea then we have, to which we give the general name substance, being nothing but the supposed, but unknown, support of those qualities we find existing, which we imagine cannot subsist sine re substante, without something to support them, we call that support, substantia; which according to the true import of the word, is, in plain English, standing under or upholding.[64]

To this Lockean conception of substance as an inferred support of observed qualities or properties, Michell added the idea that one could define properties as one pleased, with the requirement that no property so assigned could imply the absence of any other property one might name. One could not attribute to substance the property of penetrability while also attributing to it the property of solidity or impenetrability. There is at first glance an arbitrariness in Michell's prescription, for one could presumably term a substance red, a property which would not appear to

contradict such a property as penetrability. Michell's position appears to offer no opposition to this possibility though it would render either redness or substance nonsensical; perhaps this fact alone seemed to him sufficient reason for ignoring such eventualities. His argument for penetrability implied a further requirement, however, namely that any hypotheses about substance must help "to solve the appearances of nature,"[65] a qualification which effectively excluded such arbitrary definitions.

Given Michell's position on the properties of substance it becomes clear that his reversal of Baxter's argument did not involve the assumption that the only type of substance conceivable was penetrable material substance. Michell advanced a monistic hypothesis which implied that penetrable matter constituted a valid and non-self-contradictory definition of substance. He did not see materiality and penetrability as mutually exclusive properties of substance as Baxter had done, and he thought the two properties sufficient to explain natural appearances. Penetrable immaterial substance appeared to him to be an unnecessary assumption. In addition, impenetrability explained no effects and could also be abolished.

Although Priestley did not mention Newton's rules of philosophizing in his account of Michell's development of the concept of penetrable matter, the simplicity of the one-substance schema evolved by Michell seems to have been fully in accord with the prinoiple of assigning the fewest possible causes. Priestley later extended Michell's ideas on substance to psychological and metaphysical questions, and in the Disquisitions Relating to Matter and Spirit he placed his materialist argument explicitly in the context of Newton's rules of philosophizing;[66] but he mentioned in this brief account neither Newton or Locke despite the apparent influence

of both.

Both Michell and Priestley seem to have recognized the hypothetical nature of Michell's concept of penetrability and were anxious to demonstrate its applicability to optical questions, which they hoped might provide demonstrations of its validity. Both assumed light to consist of particles and they saw in the ability of light to penetrate matter a possible means of demonstrating both the corpuscularity of light and the mutual penetrability of matter. Michell's reversal of Baxter's argument provided him with a philosophical argument for the penetrability of matter, and preceded, if Priestley's dating is correct, his meeting with Boscovich, his acquaintance with Priestley, and probably the most important of his investigations into the nature of light. Baxter's thesis suggested to him the finite nature of the repulsive powers which inhibited immediate contact, and provided him with the key whereby he sought to unravel the nature of light, its emission, velocity, momentum, refleotion and refraction, and its ability to penetrate matter itself.

CHAPTER FOUR

PRIESTLEY'S ADOPTION AND ADAPTATION OF MICHELL'S THEORY OF MATTER

(1)

Joseph Priestley was interested in matter and the powers of nature before he met John Michell. In his first major scientific work, the History and Present State of Discoveries Relating to Electricity, (London 1767), he discussed the particulate nature of electricity, the role of attraction and repulsion in electrical theory, the relationship between the electric and magnetic power, and the importance of surface powers of repulsion. These ideas,

and his suggestion that natural philosophers could learn about the nature of matter through examining the powers of nature and the sensible properties of bodies[1] reveal an emphasis and intention sufficiently similar to Michell's ideas on matter and powers to have made possible their collaboration on matter and optics in the late 1760's.

Priestley conceived and prepared the History between 1765 and 1767, while on the staff of Warrington Academy. In 1765 and early 1766 he met three major electrical experimenters, Benjamin Franklin, William Watson and John Canton (all previously acquainted with Michell); the three men encouraged him in the writing of a history of electricity, supplied him with books on the subject and accounts of their own research, and suggested further electrical experiments for him to attempt.[2] Priestley did most of the reading, original experimentation and writing in 1766 and published the work in 1767. The Royal Society considered the History for the Copley Medal, but ruled it ineligible because it was not an experiment as required by Sir Godfrey Copley's bequest.[3]

In the History Priestley outlined his view of the nature of electricity in a discussion of the changes in electrical theory from the time of Robert Boyle to the work of his own contemporaries. Boyle had advanced an effluvial theory to explain electricity and had posited the return of the effluvia to the electrical body which avoided the problem of wastage by emission; and later theoreticians of the seventeenth century had advanced effluvial theories of electricity, magnetism, gravitation and light.[4]

Priestley saw the Newtonian system as a definitive break with the effluvial theories which he thought had been accepted to that time:

> WHEN the Newtonian philosophy had made some progress,

> and the extreme subtilty of light, and other effluvia of bodies, was demonstrated; so that philosophers were under no apprehension of bodies being wasted by continual emission, the doctrine of the return of effluvia was universally given up, as no longer necessary....[5]

The Newtonian philosophy introduced another mode of explanation in the form of

> ...the unknown principles of attraction and repulsion, as supposed to be properties of certain bodies, communicated to them by the Divine Being, the mechanical cause of which they scarce attempted to explain.[6]

These unknown principles, communicated to bodies by some as yet undiscovered mechanical means, later became for Michell and Priestley the active principles which constituted matter, principles themselves created and governed by God, and thus not explicable in the "mechanical" terms which implied the mere addition of a property to a passive substance. For the time being, however, Priestley was content merely to note questions about the nature and origin of attraction and repulsion which he felt the Newtonian philosophy ignored.

Priestley's interest in electrical attraction and repulsion anticipates his later work with Michell. The dynamic transformation involved in the process of electrification had been noticed by du Fay, who observed :

> ...electric bodies attract all those which are not so, and repel them as soon as they are become electric, by the vicinity or contact of the electric body;[7]

and by Wilke and Aepinus who thought

> ...that the electric fluid, when there is a redundancy of it in any body, repels the electric fluid in any other body, when they are brought within the sphere of each other's influence, and drives it into the remote parts of the body; or quite out of the body, if there be any outlet for that purpose.[8]

Michell, as we have seen, had discussed the alteration in strength and the occasional reversal of polarity which occurred when a strong magnetic pole was brought into contact with a like but

weaker pole; and his "doctrine of attractions and repulsions" dealt with the alternation of polarity in the surfaces of bodies which, in combination with the polarity of light particles, produced the alternate fits of easy transmission and easy reflection.

Priestley discussed the role of the repulsive powers of matter in impeding immediate contact and in electrical phenomena, describing, for example, Aepinus's theory

> ...that all the particles of matter must repel one another: for that, otherwise (since all substances have in them a certain quantity of the electric fluid, the particles of which repel one another, and are attracted by all other matter) it could not happen, that bodies in their natural state, with respect to electricity, should neither attract nor repel one another.[9]

He also mentioned Wilke's supposition that a mutual repulsion of homogeneous matter was responsible for the repulsion of negatively electrified bodies.[10] Priestley tentatively advanced an inverse square law of electrical attraction with explicit reference to Newton's law of gravitation;[11] but as he made no such proposal for electrical repulsion, it is not clear that he saw electrical attraction and repulsion as identical polar opposites of the same power. He rejected Aepinus's contention that electrical repulsion was in simple inverse proportion to distance,[12] but did not propose any alternative explanation.

Priestley's attitude in the History towards the aether was less decided than Michell's explicit rejection of it in magnetic phenomena. Experimenters, he said, had come to deal with phenomena more complicated than electrical repulsion and attraction, including the communication of electricity and electrical shocks. Some electricians such as Benjamin Wilson had maintained that Newton's aether could explain attraction and repulsion, but had attributed the light and smell generated by electric shocks

> ...to the grosser particles of bodies, driven from them by

> the foroible aotion of this ether.[13]

Priestley contended however that most eleotricians supposed,

> ...and with the greatest probability, that there is a fluid sui generis principally concerned in the business of electricity.[14]

He suspected that they were too hasty in their rejection of the aether:

> They seem, however, though perhaps without reason, entirely to overlook Sir Isaac Newton's ether; or if they do not suppose it to be wholly unconcerned, they allow it only a seoondary and subordinate part to act in this drama.[15]

Priestley did not combine the aether and a fluid sui generis to produce an eleotrical theory; he only noted the possible utility of the aether. He seemed favourably disposed towards the aether, though unsure of its role in electrical theory. As will be seen later, he virtually ignored the aether in some of his later scientific work, the aether going virtually unnnoticed as early as 1772 in the History of Optics, perhaps as a result of Michell's influence.

Priestley queried whether electricity was distinct from Newton's aether, and whether the eleotric fluid consisted of "some particular order of the particles" emitted from surfaces, just as Newton had supposed air and aether to be.[16] These questions indicate that Priestley regarded the eleotric fluid as a particulate substance, perhaps oaused by the aether, but probably effluvial in origin as the aether itself was supposed to be. The eleotric fluid was elastic, and its particles were therefore able to repel each other, and Priestley thought the determination of the law governing their repulsion an important task.[17]

Priestley noted the existence of repulsive powers at the surface of bodies which hindered immediate contact, just as Michell had done earlier. Light bodies lying on another body were not in

actual contact, as was shown by optical experiments and the visibility of an electric spark between stacked pieces of metal; and to ascertain how such bodies could be brought into contact he piled twenty smooth shillings and passed an electric charge through them.[18] The discharge melted all the coins on both sides, but produced no fusion. He tried more weight and achieved fusion with six pounds; but with more than six and a half pounds the coins no longer fused. He thought the large explosion in this last case might produce a brief repulsion followed by fusion, but no fusion occurred.

Priestley thus used one power of nature, namely electricity, to overcome the surface powers of repulsion possessed by metallic bodies. He did not discuss the implications of the fact that more than the necessary amount of electricity required to produce fusion was unable to achieve the same effect, though one can note in passing the possible analogy between this and Michell's observations on the alteration of strength or the reversal in polarity of a magnetic pole under the influence of a like but stronger pole. In both cases there was evidently a certain amount of power able to overcome the natural resistance (surface repulsion or magnetic resistance), beyond which level the resistance reappeared.

Priestley also used the electrical power to ascertain the conductivity of various metals, and ranked them thus: iron, brass, copper, silver, gold.[19] He did not explain the relation of different conductivities to particle structure, nor did he mention any connection between electrical conductivity and magnetism. Franklin had established the identity of electricity and lightning, and Michell had noted the fact of magnetic "resistance"; but the possibility of electrical conductivity and its concomitant, electrical resistance, being analogous to the ability of bodies to absorb magnetism did not occur to Priestley, nor did he mention the idea

that the introduction of electricity into a body containing iron could affect the magnetic power of a body.

In summary, the History of Electricity shows Priestley's first dealings with concepts central to his later ideas on matter in the History of Optics; and although there is no indication that he knew of Michell's work by 1767, there is nonetheless an interest in the nature of matter and the various theories of aether, effluvia and particle structure which indicates how he could rapidly have become so interested in speculation in the theory of matter under Michell's influence. In particular, his discussion of the surface powers of repulsion of bodies shows that he recognized by 1767 the existence of these powers which, as we saw in chapters two and three, were for Michell the cause of the apparent resistance of bodies to penetration, which resistance he thought could be overcome by the momentum of light.

(11)

In the History of Optics, 2 volumes, (London, 1772), Priestley defended the material and particulate nature of light. He examined the experimental work of his predecessors and contemporaries and their attitudes towards the nature of light. He used Michell's ideas extensively in his defence of the particulate theory against the "wave" theory advanced by Leonhard Euler; and although he also cited Boscovich, Canton and Thomas Melvill, Michell's ideas descri-

bed in chapter three of this thesis were his chief inspiration, as I hope to show in the remainder of this chapter.

Priestley also discussed vision, colour theory and certain technical questions about astronomical instruments, but in his treatment of these subjects the nature of light was still a central concern. The History of Optics with its articulate defence of the corpuscular theory of light, its reformulation of Newton's ideas on the nature of light, and its rejection of his notion of the impenetrability of matter, all along lines proposed by Michell, shows Priestley to have been, at least in this one major work, anything but a random observer and experimenter and naive follower of Newton on light, matter and the nature of hypotheses.

Priestley delineated the two major positions of his contemporaries on light, placing himself along with Michell, Boscovich, Canton and Melvill in descent from Newton's corpuscular theory, and citing Euler as the successor to the undulatory theory of Christiaan Huygens.

Priestley said of the two great rival theories that Newton conceived of light as

> ...consisting of particles emitted from luminous bodies;[20]

while Huygens

> ...supposed light to consist in vibrations propagated from the luminous body, through a subtle etherial medium.[21]

Newton said in Query 29 of the Opticks:

> Are not the Rays of Light very small Bodies emitted from shining Substances? For such Bodies will pass through uniform Mediums in right Lines without bending into the Shadow, which is the Nature of the Rays of Light.[22]

Newton did not mention in this passage, however, the subtle aetherial medium which he elsewhere proposed as the medium through which light traversed.[23] Huygens had maintained in chapter one of his Treatise on Light[24] that light consisted of an aetherial substance

filling the solar system, which substance was set in vibratory motion by the impact of the particles of the luminous body. The waves were then transmitted in straight lines while the aetherial particles vibrated, each transmitting its motion to its neighbour.

Euler was the successor to the latter theory, describing light as an agitation of the aetherial particles filling space, caused by the communication of the extremely rapid vibrations of the sun's particles to the ether.[25] The extreme elasticity and subtlety of the aether explained the great velocity of light, the very size of that velocity being for him a refutation of any emanation theory;[26] and further, the wave theory avoided the problem of the diminution of the sun in a way which emanation could not.[27] Euler said that Newton's supposition of a void between the sun and the earth required the actual emanation of light particles with incredible force, there being no medium through which vibrations could be transmitted; and added that Newton claimed that the planets experienced no resistance in their motion around the sun, while at the same time filling the interplanetary space with the light not only of the sun but of the stars which would surely have interfered with planetary motion.[28]

Priestley discussed Euler's objections to the corpuscular theory at length on the basis of the work of several other scientists.[29] Euler's first objection, that, as Priestley put it, the sun would be diminished by emanation if light were corpuscular, Priestley countered by citing Michell's experiment on the momentum of light.[30]

Michell had noted that the copper-plate in the windmill-type instrument had moved about one inch per second when struck by the sun's rays focussed from a mirror.[31] Priestley showed how Michell determined the mass of a light particle on the basis of that

observation, and his calculation of the resulting diminution of the sun's mass over a period of six thousand years:

> ...a quantity which would have shortened the sun's semidiameter no more than about ten feet, if it was formed of matter of the density of water only.[32]

In the approximately six thousand years that many of his contemporaries thought had elapsed since the Creation,[33] Michell's figures indicated that virtually no diminution of the sun would have taken place through the emission of particles of light, and Priestley clearly found in this application of Michell's results from the momentum experiment a refutation of Euler's first objection to the materiality of light.

Priestley then discussed another of Euler's objections, that particles of light would fill the solar system and impede the motion of the planets, referring to the arguments of Canton, Melvill and Boscovich. John Canton had suggested in a paper in the Philosophical Transactions (1768), that mutual interference of light particles vanished if one supposed an interval between the emission of successive particles: if one hundred and fifty particles left each lucid point of the sun's surface every second, each particle would be more than one thousand miles from its nearest neighbour so that the interference was highly improbable.[34] He assumed, as had Michell in his 1767 paper, that light particles were emitted in rapid succession; but he noted in addition that a large distance between particles was implicit in their emission over time.

Thomas Melvill (1726-1753) had argued that probably all points on the horizon sent light to all other points, unless opaque bodies interfered; and light passed from stars without interference by light from other stars and systems or by any aetherial medium.[35] He concluded that light must be very rare indeed, and that, in

Priestley's words:

> ...the semidiameters of two of the nearest particles, in the same, or in different beams, soon after their emission, are incomparably less than their distance from one another.[36]

Melvill thought, as Priestley noted, that Boscovich's supposition of particles possessing "an insuperable impulsive force" increased the likelihood of the interference of particles.[37] Priestley wrote that he himself would

> ...suppose the force of the sphere of repulsion, next to any of the indivisible points which constitute what we call solid bodies, not to be absolutely infinite, but such as may be overcome by the momentum of light, which will obviate the objection of Mr. Melville above mentioned.[38]

Thus, if those forces could be overcome by the momentum of light, light particles would simply pass through each other. Priestley's proposal supposed a finite repulsive force co-terminous with the unextended, indivisible point itself, a suggestion consistent with Michell's theory of matter as described in the History, but opposed to the infinitely strong repulsive force which was one of Boscovich's fundamental postulates.

In summary, Priestley modified Boscovich on the extreme smallness of light particles to overcome Melvill's objection which was itself unsound. Priestley's argument, based on Michell's proposition that the repulsive powers of matter could be overcome by light, was reasonable: but Canton, Melvill and Boscovich had already shown that interference was highly improbable. Nonetheless, these three men demonstrated to Priestley's satisfaction that Euler's second objection to materiality, that light particles would fill the solar system and interfere with the motion of the planets, was invalid because of the "extreme subtilty" of the particles and the enormous distance between them.

Priestley cited Michell and Boscovich in his refutation of Euler's third objection, that light particles could not penetrate

transparent bodies even with their great velocity. Boscovich had ascribed to them sufficient momentum to penetrate the surfaces and apparently solid parts of a body, for he believed these to consist only of forces surrounding the point-atoms which were the basic units of matter. Michell believed that light particles were emitted from the sun by an incredibly strong repulsive power, and reflected or refracted by equally strong powers at the surfaces of bodies. In the absence of such a repulsive power transmission occurred and particles passed through the transparent substance with no difficulty. Priestley's use of the arguments of Michell and Boscovich is the topic of the next section.

(111)

Priestley probably first read Boscovich's published works and wrote his account of Boscovich's theory after he had learned of Michell's ideas on matter and light, and as I hope to show in this section, his modifications of Boscovich's theory reveal Michell's influence and indeed seem explicable only by assuming that Priestley had already accepted Michell's views on immediate contact, the role of powers, and the mutual penetrability of matter.

Priestley had met Michell in late 1767 or early 1768, and had apparently completed a draft of the History of Optics by December 1770.[39] Robert Schofield has shown that Priestley acquired three of Boscovich's works, including the Theoria Philosophiae

Naturalis, at some date after early 1771 and before the publication of the History in 1772.[40] It thus seems apparent that Priestley read Boscovich about three years after the beginning of his discussions with Michell and the commencement of his work on the History, and some months after he had completed a preliminary draft of the History.

Michell's role in Priestley's preparation of the History of Optics was analogous to that of Franklin, Watson and Canton with respect to the History of Electricity. Michell was Priestley's sole major collaborator in the former and lived near Leeds at a time when Priestley was far from his earliest scientific mentors. The three electricians had already published much of their work, but Priestley was the only published source for many of Michell's ideas on the emission, momentum and refraction of light and the penetrability of matter.

Priestley is well known as a disseminator in England of Boscovich's ideas, but his sense of debt to Boscovich is now seen to be exaggerated.[41] The influence of Michell, which he generously acknowledged, has not been examined in detail despite its crucial importance, and indeed that influence helps explain Priestley's misinterpretations and modifications of Boscovich, which otherwise seem arbitrary.

Boscovich propounded his theory of point-atomism in a series of books beginning in 1745, and explained his physical theory most fully in the Theoria Philosophiae Naturalis Redacta ad Unicam Legem Virium in Natura Existentium, translated as A Theory of Natural Philosophy deduced from a Single Law of Forces existing in Nature. The first edition appeared in Venice in 1758, but Priestley used the third and definitive edition which was published in Venice under the author's supervision in 1763.

Boscovich summarized his theory thus:

> I find that between all points of matter there is a mutual force depending on the distance between them, & changing as this distance changes; so that it is sometimes attractive, & sometimes repulsive, but always follows a definite continuous law.[42]

Matter consisted of simple, non-extended points which

> ...are subject to a determination to approach one another at some distances, & in an equal degree recede from one another at other distances. This determination I call 'force'; in the first case 'attractive', in the second case 'repulsive'; this term does not denote the mode of action, but the propensity itself, whatever its origin, of which the magnitude changes as the distances change;....[43]

Thus the propensity of any two points to attract or repel each other changed with distance, but the forces became at smaller distances

> ...indefinitely greater and greater, as the distances are diminished indefinitely, in such a manner that they are capable of destroying any velocity, no matter how large it may be, with which one point may approach another, before ever the distance between them vanishes.[44]

An insuperable force intervened between two points at closest approach, and further, two points could not come into immediate contact because they were mathematical points and hence possessed neither extension nor parts;

> ...if the distance between two points of matter should become absolutely nothing, then the very same indivisible point of space, according to the usual idea of it, must be occupied by both together, & we have true compenetration in every way.[45]

But Boscovich denied immediate contact of points, for it was infinitely improbable that two points would occupy the same place. "Apparent compenetration" of two bodies would result in

> ...no direct encounter of one point of matter with another point of matter; & thus there can be no compenetration, even apart from the idea of repulsive forces.[46]

Boscovich supposed the apparent solidity of bodies to result from the forces existing between the constituent points. A body could pass through a plane of forces if it possessed enough momentum:

> We can illustrate the idea by the example of an iron ball

> which is required to pass across a plane, in which lie scattered in all positions a great number of magnetic masses possessed of considerable force. If the ball is not projected with a certain very great velocity, even if its direction is such that it is not bound to meet any of the masses, yet it will not go beyond those masses; but its motion will be checked by their attractions. But if the velocity is great enough, so that the actions of the magnetic forces only last for a sufficiently short interval of time, then it will certainly get through & beyond them without suffering any sensible loss of velocity.[47]

Thus did Boscovich illustrate his conception of penetrability:

When a small particle possessed enormous velocity there occurred

> ... that apparent compenetration that we have in the case of light, as it passes through a homogeneous space with a perfectly free rectilinear motion.[48]

But as he noted, that compenetration was only apparent.

Boscovich recognized his debt to the physical theory of Newton and Leibniz but stressed the distinctive nature of his own theory:

> ...it has very much in common with both, & differs very much from either; &, as it is immensely more simple than either, it is undoubtedly suitable in a marvellous degree for deriving all the general properties of bodies, & certain of the special properties also, by means of the most vigorous demonstrations.[49]

He borrowed from Newton the concept of the "mutual forces, which vary as the distances of the points from one another vary,"[50] and added to Newton's attractive force the idea of a repulsive force which

> ...was suggested by Newton in the last of his 'Questions on Optics', & he illustrated it by the example of the passage from positive to negative, as used in algebraic formulae.[51]

Boscovich advanced a single law governing the relations between any two points instead of what he called Newton's "three principles of gravity, cohesion & fermentation."[52] Boscovich explained cohesion by the strong mutual attractions between points at distances greater than those at which the infinitely strong innermost sphere of repulsion began, while gravity was an attractive force which operated at large distances where the alternation between attraction and repulsion ended, decreasing as the square of the distance as

in Newton's law.

Leibniz had provided Bosoovioh with the idea of simple, unextended points,[53] but Boscovich had modified this concept to one of points incapable of contact, thus rendering impossible continuous extension derived "from the idea of consecutive, non-extended points touching one another...."[54] Though he accepted continuity as a basio law of nature, Boscovioh saw its operation not in extension but in the continuous alteration in strength of the attractive and repulsive forces in nature. The gradual reduotion of velocities of two approaching bodies stopping them before actual immediate contact was his view of the activity of continuity in nature.

Boscovich admitted the homogeneity of points in contrast with Leibniz's assumption of different categories of substance, writing of his own theory:

> ...it admits homogeneity amongst the elements, all distinotion between masses depending on relative position only, & different oombinations of the elements;....[55]

All bodies and all substances including particles of light were constructed of homogeneous, non-extended points, and the properties of bodies and substances were ultimately explicable to Bosoovioh by the relationship between point-atoms.

Priestley used Boscovich's theory as part of his demonstration of the material and particulate nature of light and its ability to penetrate matter, but modified it considerably on the basis of Michell's ideas, as I hope to show. Boscovich, he began,

> ...supposes that matter is not impenetrable, as has been, perhaps, universally taken for granted, but that it consists of physical points only, endued with powers of attraction and repulsion, taking place at different distances; that is, surrounded with various spheres of attraction and repulsion, in the same manner as solid matter is generally supposed to be....[56]

Already Priestley was modifying Boscovich's theory of matter.

Firstly, Priestley referred to the point-atoms as "physical points" whereas Boscovich saw them as mathematical points only. In saying that Boscovich's point-atoms were "endued with powers of attraction and repulsion taking place at different distances", Priestley implied that the chief properties of the point-atoms were the powers of attraction and repulsion. The latter can be spoken of as powers of nature or physical powers from the Greek physis for nature, which may explain why Priestley spoke of them as physical points despite Boscovich's clear definition of them as mathematical points possessing no parts or extension. Priestley's description of Boscovich's point-atoms seems closer to Michell's idea that substance was located where its properties and powers existed,[57] and to his concept of the primacy of powers rather than point-atoms.

Priestley spoke of powers "taking place at different distances" which presented the apparent paradox of two properties of a substance being and acting where the substance was not. Newton had conceived of gravitational attraction acting at a distance, and Michell and Priestley had examined powers of nature acting at a distance in their respective studies in magnetism and electricity. Michell and Priestley's conception of these powers and their relationship to substance was not merely that of action at a distance as Newton and indeed Boscovich had assumed. For Boscovich point-atoms were the basic constituents of matter, their existence being the necessary and sufficient condition for the attractive and repulsive forces of nature which came into being as relations between points.

Priestley's conception, based on Michell's, was that of powers of nature underlying and constituting matter. Michell's view of matter as described in chapter three was of attractive and repulsive powers constituting material particles; powers were basic and

particles were manifestations of powers. This was the reverse of Boscovich's theory, and Priestley's modification of the latter's point-atoms can perhaps best be explained by assuming that Priestley had accepted Michell's monistic theory of the identity of power and substance, and therefore failed to notice that Boscovich conceived of points and powers as logically and physically distinguishable entities.

In his second modification of Boscovich's theory Priestley said that Boscovich supposed matter to be penetrable, yet later he implicitly contradicted this assertion when he suggested in his discussion on the interference of light particles that the innermost sphere of repulsion of any point should not be supposed, as Boscovich did,

> ...to be absolutely infinite, but such as may be overcome by the momentum of light....[58]

He thus recognized that Boscovich supposed points to be impenetrable, and stated his belief that this position should be modified, for Priestley unlike Boscovich supposed all matter, including point-atoms, to be penetrable. Priestley's self-contradiction thus indicates a major modification of Boscovich's theory, and one well worth examining.

That Priestley denied the impenetrability of point-atoms seems clear from another statement:

> ...M. Boscovich makes this nearest power of repulsion not to extend to any real space, but to be confined to the indivisible point itself,.../and hence/ the chance of such points impinging upon one another is so little, that it needs not to be considered at all.[59]

In fact, however, Boscovich conceived of simple, non-extended points with an insuperable power of repulsion extending to a finite distance. Priestley perhaps came to see the point itself as the location of the repulsive power, an incorrect reading of Boscovich,

because of his misunderstanding of the mathematical nature of Boscovich's points which made compenetration infinitely improbable,[60] and his failure to recognize that the infinitely strong repulsion surrounding those points was one of the basic postulates of Boscovich's theory. Priestley was correct in saying that collisions were infinitely improbable, but this was not because the nearest power of repulsion was confined to the points itself, for Boscovich did not make such a suggestion.

In discussing Boscovich Priestley stated his own view that matter consisted of

> ...powers, such as we know, do, in fact, exist in the same place, and counterbalance, or overrule one another....[61]

Thus Priestley's conception of penetrability differed greatly from Boscovich's, despite Priestley's assumption that Michell and Boscovich had identical theories. Priestley's conception of matter consisting solely of powers rendered all categories of matter including particles and point-atoms penetrable, a position based on Michell's, and the reverse of Boscovich's assumption that matter consisted of impenetrable point-atoms, the relationships of which constituted powers of attraction and repulsion.

A third modification of Boscovich occurred when Priestley spoke of points "surrounded with various spheres of attraction and repulsion", perhaps a reference to Boscovich's concept of the alternate attractive and repulsive forces existing between two points at various distances. However Priestley did not describe the alternation between strong attraction and strong repulsion, and did not indicate that Boscovich's theory assumed a continuum. Indeed Priestley's use of the term "sphere" suggests he supposed no continuity in alteration of strength, unless he was thereby referring to the spheres of zero attraction and repulsion which

surrounded a point at distances where the alternation between very small attraction and repulsion occurred. Spheres so described around the point would contain, alternately, areas or spheres of attraction and of repulsion. Priestley's usage can perhaps be seen as a means of describing Boscovich's concept concisely and of suggesting its three-dimensionality; yet his other modifications of Boscovich's theory and the over-simplification involved in this use of the term "sphere" make one wary of a purely Boscovichean interpretation.

A reading of the text cannot readily explain Priestley's use of the term. One can use the word "sphere" literally to describe a purely geometrical idea; the entirety of a spherical object, or one of its sections or "shells"; or figuratively as in a "sphere of influence". Priestley used the term figuratively in his description of the overcoming of the powers preventing immediate contact:

> This difficulty we can overcome; and having got within one sphere of repulsion, we fancy that we are now impeded by the solid matter itself.[62]

This figurative usage suggests care needs to be taken in interpretation, particularly with Priestley's wording:

> ...surrounded with various spheres of attraction and repulsion, in the same manner as solid matter is generally supposed to be....[63]

Rather a commonly-held idea in the mid-eighteenth century, the idea of "spheres" of attraction and repulsion surrounding solid matter (presumably solid bodies) was formulated most clearly, though in different forms, by Priestley, Michell and Boscovich. Boscovich's law of forces resulted in alternation between attraction and repulsion at and just beyond the surfaces of bodies; but this was Priestley's first suggestion that he himself (and Michell) had similar ideas. Both men had written about surface repulsive powers but neither had fully

described his conception of the relation of the powers to surrounding spaces, nor, unfortunately, did Priestley do so here.

Thus Priestley's view of points surrounded by spheres of attraction and repulsion was a simplification and distortion of Boscovich's concept of forces. It was, however, similar to Michell's theory of magnetic particles consisting of points of attraction and repulsion, with the spheres of attraction and repulsion surrounding each of the two points of a particle producing by their interaction various areas of attraction, areas of repulsion, and areas in which the two powers counterbalanced. Priestley's third modification of Boscovich's theory thus showed Michell's influence, just as did the first and second.

The next stage of Priestley's description of Boscovich's theory concerned the relevance of Boscovich's point-atomism to the penetrability of matter; once again Priestley introduced a change in Boscovich's theory:

> ...Provided, therefore, that any body move with a sufficient degree of velocity, or have sufficient momentum, to overcome any powers of repulsion that it may meet with, it will find no difficulty in making its way through any body whatever; for nothing will interfere, or penetrate one another, but powers, such as we know, do, in fact, exist in the same place, and counterbalance, or overule one another; a circumstance which never had the appearance of a contradiction, or even of a difficulty.[64]

Priestley's contention that a body could overcome repulsive powers if it possessed sufficient momentum was analogous to Boscovich's argument that an iron ball with a high velocity could pass through a plane of magnetic force.[65] Priestley's next remark that if a body possessed sufficient momentum to overcome powers of repulsion

> ...it will find no difficulty in making its way through any body whatever...,[66]

was similar to Boscovich's supposition that small particles moving at high velocity could pass through a body, as when light passed

through a transparent substance. Boscovich, as we have seen, regarded this as merely "apparent" compenetration.

Priestley also indicated that the passage of one body through another was only the interference or penetration of powers, which was different from Boscovich's description of apparent compenetration as merely the passage of one organized fabric of points and their powers through another such fabric.[67] Boscovich considered the mutual interference of points infinitely improbable, but Priestley thought that particles possessing enough momentum would simply pass through other particles which were themselves but manifestations of finite powers.

Priestley's proposal that the innermost sphere of repulsion could be overcome by the momentum of light seems to confirm this supposition.[68] Thus there appears in Priestley's description of Boscovich's theory a shift of emphasis from apparent compenetration to the true compenetration proposed by Michell, though Priestley gave no indication that his account modified Boscovich's meaning.

Priestley's acceptance of true compenetration appears in the following passage:

> The most obvious difficulty, and, indeed, almost the only one that attends /Boscovich's/ hypothesis, as it supposes the mutual penetrability of matter, arises from the idea we have formed of the nature of matter, and the difficulty we meet with in attempting to force two bodies into the same place. But it is demonstrable that the first obstruction arises from no actual contact of matter, but from mere powers of repulsion. This difficulty we can overcome....[69]

He was speaking here of the mutual penetrability of matter not of bodies (as Boscovich had done). If matter consisted for Priestley of "physical points only, endued with powers of attraction and repulsion", to speak of the mutual penetration of matter seems to include the compenetration of physical points. Priestley claimed that the usual rejection of mutual penetrability arose from an

inability "to force two bodies into the same place,"[70] (Boscovich's "apparent" compenetration). However Priestley believed that all the repulsive powers preventing penetration could be overcome: he had himself overcome the surface repulsion of pieces of metal by electricity;[71] and Michell had argued that the momentum of light particles enabled them to penetrate matter. Priestley went on to argue that having overcome the first difficulty

> ...we fancy that we are now impeded by the solid matter itself. But the very same is the apprehension of the generality of mankind with respect to the first obstruction. Why, therefore, may not the next be only another sphere of repulsion, which may only require a greater force than we can apply to overcome it, without disordering the arrangement of the constituent particles, but which may be overcome by a body moving with the amazing velocity of light.[72]

Though actual physical pressure could overcome some of the repulsion, it would also alter the shape of the body and the arrangement of its constituent particles. Light particles could penetrate transparent substances without disordering the particle arrangement, and since transparency depended on homogeniety of structure (a fact noted by Newton, and known to Michell, Priestley and Boscovich) Priestley perhaps had this in mind when he mentioned the arrangement of particles, for continuous transmission does not lessen the transparency of a substance.

Priestley clearly regarded Michell and Boscovich's theories as virtually identical:

> This ingenious hypothesis, at least, one that is the same in every thing essential, occurred also to my friend Mr. Michell, in a very early period of his life, without his having had any communication with M. Boscovich, or even knowing that there was such a person.[73]

In the section which followed (discussed in chapter three) Priestley described Michell's abolition of the immaterial and penetrable powers and material and impenetrable matter of Baxter's system, and their replacement by a single penetrable and material substance.

Baxter's material partioles ceased to exist as hard, massy, solid objects, and the remaining substance was oompletely penetrable.

Michell's argument for penetrability seemed to imply what Boscovich termed "true compenetration". On this issue Miohell appears to have differed completely from Boscovioh, and Priestley favoured compenetration throughout his description of Bosoovich's theory. His proposal of a less than infinitely strong innermost sphere of repulsion was oonsistent with Michell's opinion that light could penetrate the repulsive powers surrounding matter, and seems oonclusive evidence that Priestley favoured true compenetration.

Thus his final modification of Boscovich resulted in the rejection of Bosoovich's basio oonoepts of absolutely impenetrable point-atoms and the impossibility of immediate contaot. For Priestley as for Michell powers of attraotion and repulsion oonstituted matter. The implications of this position borrowed from Miohell are far-reaching, and indicate a wide divergence from Boscovioh's metaphysical assumptions as well as his physical theory. In the following chapters the metaphysical assumptions underlying Miohell and Priestley's theory of penetrable matter will be discussed in detail, and the differences with Boscovich will help to clarify the relation of Miohell and Priestley's ideas on matter to those of Newton and Locke from whom they borrowed much and ohanged a great deal, and to those of Boscovich with whose ideas they shared an emphasis on the role of forces, but with whom they differed on penetrability, immediate contact, and the role of powers in the nature of matter.

In summary, Priestley read Boscovich's Theory late in the preparation of the History of Optics, probably at some date between January and September 1771.[74] The theory of matter presented in

the Theory seemed to answer easily and by means of a single law, a number of objections to the materiality of light, and it was particularly useful in refuting Euler's objection to the possibility of partioles of light penetrating transparent substances.

Miohell however had already provided Priestley with an explanation of this phenomenon with his "doctrine of attractions and repulsions", his work on the momentum of light and the repulsive powers of matter, and his concept of the penetrability of matter. Michell had not published his ideas on these subjects while Boscovich had set forth his ideas systematically and thoroughly. Perhaps Melvill's references to Boscovich, and almost certainly Michell's urgings led Priestley to acquire the Theory even though he had completed a draft of the History by that time. Priestley included discussions of Boscovich in the History; the relevant sections were printed by October 1771.

As I have tried to show in this section, Priestley's account of Boscovich's ideas on points, powers and penetrability included modifications which were probably the result of his familiarity with Michell's ideas on these subjects. Boscovich's point-atoms became for Priestley physical points consisting of powers of attraction and repulsion; their impenetrability was abolished; and the continuous alteration of the strength between strong attraction and strong repulsion in the space around the point-atoms was replaced by "spheres" of powers. The net result was the rejection of Boscovich's concept of the purely theoretical possibility of apparent compenetration of bodies in favour of true compenetration of bodies and particles. Priestley rejected Boscovich's idea of the impossibility of immediate contact and of the infinitely strong repulsion surrounding point-atoms, and defended on the basis of Michell's position that the repulsive powers of matter

were enormous but finite, the mutual penetrability of matter.

(iv)

The keys to Priestley's theory of matter in the History of Optics lie in Michell's ideas on light and matter outlined by Priestley in the same work. Michell's "doctrine of attractions and repulsions" explained to Priestley not only the nature, emission, momentum, refraction and reflection of light, but also the repulsion at the surfaces of bodies which he had noted in the History of Electricity. In addition he accepted Michell's arguments for the penetrability of matter and for the materiality of all substances, while recognizing the hypothetical nature of the reasoning that Michell advanced. He also adopted Michell's position that the properties of a substance were all that could be known of it and were located in the same place as its powers. In this section I will discuss the relationship of Priestley's ideas on matter in the History of Optics to Michell's, and point out how they differed in certain respects from those advanced by his mentor.

Priestley presented a dynamic theory of matter for the first time in the History of Optics, for one can see implicit in his discussion of Boscovich and Michell on matter a conception of his own of matter as consisting of physical powers possessing powers of attraction and repulsion (as in his description of Boscovich's theory which is really a distinctive interpretation of that theory),

perceptible through the physical properties of bodies. His implied dynamic theory of matter later provided the basis for his "materialist" psychology and metaphysics.

His own and Michell's optical researches provided Priestley with the ideas about the nature of matter for which he had expressed his hope in the History of Electricity. To establish the materiality of light required the reconciliation of its particulate nature with its ability to penetrate transparent substances. Michell's demonstration of light's momentum and his explanation of its emission, transmission, reflection and refraction by attractive and repulsive powers provided Priestley with a means of reconciling these two ideas. Michell had used the polarity of light particles to explain the interaction of light with other material bodies by the interaction of powers, as an alternative to action through immediate contact. Such a dynamic theory of the action of bodies on each other through the interaction of their powers was acceptable to Priestley, particularly in view of the concern he expressed in the History of Electricity over the laws governing the mutual attraction and repulsion of electric particles.

Priestley recognized with Michell the finite strength of repulsive powers at the surfaces of bodies, having himself noted this in his experiment involving the fusion of pieces of metal by electricity in the History of Electricity. In their supposition of the penetrability and dynamic nature of matter Priestley and Michell adopted a theory different from the corpuscular theory of Canton and Melvill, and different also from the dynamic theory of Boscovich. Priestley and Michell shared with the other three an acceptance of the materiality, extreme smallness and high velocity of light particles, and with Melvill and Boscovich the idea that particles of such smallness could pass through a body

without interfering with its particles.

Yet they went farther than Melvill and Canton in proposing a theory of powers to explain both light's repulsion and enormous momentum and the apparent solidity of matter; and their theory differed from Boscovich's in its assumption of the finite nature of the repulsive powers of physical points and the possibility of their mutual compenetration.

Priestley's theory of matter in the History of Optics was dynamic in three basic senses with its assumptions that active or "dynamic" powers constituted matter; that these powers caused perception; and that the relationship between matter and its properties and between matter and powers was an active one. The relationship itself formed a vital element in the continuing existence of each. Priestley developed this dynamic theory of matter further in his psychological and metaphysical publications of the mid-1770's, discussed in the next chapter; and in these fields he advanced a dynamic interpretation of the material substance of mind and its relationship to observed behaviour (the key to human nature, as properties were to the nature of substance), and a dynamic explanation of powers and their relationship to the universe and to its Creator.

The dynamic theory of matter which Priestley advanced in the History of Optics provided the basis for this later work. The theory was adopted from and virtually identical with Michell's except for the concept of "physical points" which Priestley seems to have adopted from Boscovich and adapted to fit Michell's theory of penetrability; and the epistemology and metaphysical assumptions underlying Priestley's theory were, as we shall see, very similar to Michell's transformation of the ideas of Locke, Newton and Baxter into a dynamic theory of penetrable matter constituted

of the powers of attraction and repulsion and a theory of substance in general as the manifestation of powers made perceptible to the human observer through its properties.

CHAPTER FIVE

PRIESTLEY'S APPLICATION OF MICHELL'S THEORY OF MATTER

Between 1772 and 1777 Priestley applied the theory of matter gained in large part from Michell, to psychology, metaphysios, and theology. Michell's assumption that matter was a manifestation of powers opened for Priestley the possibility of reassessing completely the psychological, metaphysical and theological ideas based on a oomplete dichotomy between matter and immaterial spirit.

Priestley concluded that matter could support thought, and his rejection of the extreme view of immaterial substance as having nothing in common with matter led him to think that this extreme view had distorted the issue of the nature of the soul, of Christ, and of God.

Priestley was by the 1770's involved with the Whig circles in which Michell's friend and patron, Sir George Savile, played a prominent role. During this period Priestley and Savile co-operated on the furthering of the dissenting cause and Priestley's entry in 1773 into the Earl of Shelburne's employ as librarian brought him into contact with the political world of England. During his years with Shelburne (1773-1780) Priestley was able to combine an active defense of the dissenters, and later of the American colonists, with metaphysical speculations and continued work in natural philosophy made possible by the income received from the Earl.

Pneumatic chemistry was by this time his principal interest in natural philosophy, accompanied by research into the physiology of respiration and other biological processes. These subjects dominated his scientific work for the rest of his life and his interest in electricity and optics subsided almost completely. His ideas on matter and powers were important to his new researches and he was concerned with applying these new ideas to those subjects as we shall see later in this chapter.

During the 1770's he was also reformulating his metaphysical views. His acceptance of David Hartley's doctrine of necessity, and Hartley's optimistic views of human nature and of God's benevolence had undermined his Calvinist beliefs while he was still at the academy at Daventry, and by the early 1770's he had become a unitarian. Michell's dynamic theory of matter now enabled him

to formulate a "materialist" metaphysic in which his views on matter, the powers of nature, man's mind, the nature of Christ and of God, and of God's agency in the universe could be combined in a single dynamic system.

(1)

Priestley published the first volume of the Institutes of Natural and Revealed Religion in 1772, and in it he discussed natural religion and its relation to revealed religion, and outlined briefly his views on immortality, the nature of matter and the human mind.

The preface of the first volume is dated at Leeds in March 1772, but there is in the work no indication of the dynamic theory of matter which he had printed in the History of Optics by October 1771.[1] Neither of the later two volumes published in 1773 and 1774 respectively mentioned a dynamic theory of matter nor hinted at its possible relevance to psychology or metaphysics, even though the second referred to David Hartley and the third was being published at about the time Priestley was preparing his "dynamic" introductory essays to Hartley's Theory of the Mind (1775). Perhaps, one may speculate, Priestley had conceived and written by 1770 or 1771 the text of the Institutes which were intended as a summary and formalization of religious instruction he had given to young members of his congregation in Leeds. His work in chemistry, his various

religious publications, and his preparation of the History of Optics occupied much of his time in 1771 and 1772, and perhaps he did not have the time or the inclination to revise the Institutes to keep them in harmony with his rapidly-changing ideas on matter. As his own realization of the psychological, metaphysical and finally theological significance of these ideas was a gradual process which lasted through much of the 1770's, it is unlikely that he would have been concerned in 1772 to revise a text to take into account new ideas on matter the importance of which he was only beginning to realize for himself. Thus volume one of the Institutes may possibly provide us with Priestley's view of matter unaffected by his exposure to the ideas of Michell or Boscovich.

Priestley put forward a dualist theory of substance in volume one of the Institutes, contrasting the activity of spirit with the passivity of matter:

> SINCE matter is a substance incapable of moving itself; since it can only be acted upon, and we cannot connect with it the idea of action, or an original power of acting upon other things, we cannot but conclude that God is an immaterial being, or a spirit.[2]

God as original cause of the universe could not be material for he was active and self-moving and possessed "an original power of acting upon other things," all of which properties were inconsistent with the passivity of matter.

It appears to me that the concept of matter's inability to originate motion here advanced by Priestley remained central to his conception of substance through all the modifications which the following years brought to his view of matter. The dynamic role which he here ascribed to God as "original power" remained a constant in his theory of substance; and at no time did he attribute to any created substance, whether matter, powers or mind, an original,

self-moving activity. Eaoh affeoted the other in a dynamio relationship but none was self-moving. Motion and aotivity were the result of the interplay of powers and/or substance, but the interplay produced the aotivity, and eaoh power or substance was dependent on the others for its aotivity. Only unoreated Deity was self-moving and his power was the ultimate cause of all motion in his oreated universe. Priestley's dynamio metaphysics as desoribed in the Institutes thus appears to have preceded his dynamio theory of matter in whioh the attributes of matter and spirit were fused in a single "material" substanoe, and neither in this nor later works did he attribute self-motion to any oreated substance.

In the Institutes Priestley speoulated about the properties of substanoe, but insisted

> ...we must aoknowledge ourselves to be altogether ignorant of the nature or essence of God, and, indeed, of matter too; since, to the properties of length, breadth, and thioknness, we oannot be oertain but that other properties, of very different natures, suoh as even perception and intelligence, may be superadded.[3]

Thus he regarded man as ignorant of the nature of God and substance, but thought that knowledge of their properties oould be obtained. This position is virtually identioal to Looke's in the Essay that we could know nothing of the nature of any substanoe, but that we nonetheless suppose it to be a

> ...support of such qualities whioh are capable of produoing simple ideas in us....[4]

Locke also suggested that matter may oonoeivably support perception and intelligenoe, and in a later work Priestley attributed this ooncept explicitly to Looke.[5] Thus the conoept of substance advanced in volume one of the Institutes was similar to and probably adopted from Looke's writings.

Priestley arrived at a negative oonolusion concerning God's nature from his consideration of matter, for he believed it unlikely

that matter,

> ...so sluggish and inert, should be the original cause and fountain of life, action, and motion to all other beings.[6]

Thus, even given our complete ignorance

> ...concerning the nature of matter, and of the properties which may, or may not be compatible with it, there seems to be sufficient reason to conclude, that the essence of God cannot be matter, but something very different from it, which we therefore call immaterial, or spiritual.[7]

God, he argued in this work, must be an immaterial being, because matter is sluggish and inert. As we shall see, his ideas on matter's dynamic nature led to his reconsideration of this concept of God during the mid-1770's.

Priestley mentioned in the passage just quoted the idea of properties being compatible with the nature of a substance. In the earlier quotation concerning man's ignorance of substance he spoke of perception and intelligence being somehow superadded to matter. Unfortunately he did not clarify the concepts of "compatibility" and "superadding". It is unclear how a property could be judged compatible with the nature of a substance if that very nature is unknown and unknowable. In the History of Optics (1772) Priestley adopted Michell's position that the properties of a substance must be compatible with each other which was a more reasonable criterion of compatibility if one assumed the nature of the substance to be unknowable. The concept of superadded properties became an important part of Priestley's materialist psychology; but in the Institutes, volume one, the relation between substance and its properties was not discussed in detail. All one can note is the introduction there of the two concepts of compatibility and superaddition.

Priestley discussed the powers of nature in section iv which dealt with God's attributes deduced "from the consideration of his

power, wisdom, and goodness jointly."[8] Just as matter could not move itself,

> ...so all the powers of nature, or the tendencies of things to their different motions and operations, can only be the effect of the divine energy, perpetually acting upon them, and causing them to have certain tendencies and effects.[9]

A power of nature was thus for Priestley a tendency possessed by objects as a result of the perpetual action of divine energy. He did not speak of such divine action as in any sense miraculous, though he did in volume two speak of miracles as suspensions of natural laws by God in order that his creatures might better understand some important truth.[10] Rather, such divine energy producing motions, operations and powers was lawful and constant; and such divine interventions as occurred were not adjustments of the operation of the universe but rather means of teaching men divine truths.[11] They took place when God suspended his ordinary activity in constantly willing the universe and altered the usual course of events to draw attention to some particular truth.

Priestley concluded that a dynamic relation between God and his created universe underlay all motion in nature:

> It follows from these principles, that no powers of nature can take place, and that no creature whatever can exist, without the divine agency; so that we can no more continue, than we could begin to exist without the divine will.[12]

Priestley assumed such a relationship to be responsible for the motion of inert matter. The theory as outlined here seems to have been similar to that of Andrew Baxter who assumed as we have seen that immaterial powers caused the motion and cohesion of lifeless particles. It is not clear whether Priestley had read Baxter by this time, though five years later he cited Baxter in the Disquisitions Relating to Matter and Spirit (1777) as the "ablest defender" of the immaterialist position.[13] His adoption of a theory similar to Baxter's may help explain his interest in Michell's transform-

ation of Baxter's immaterial system. Furthermore, Priestley's metaphysics shared with Baxter's a dynamic interpretation of the relationship between God and the universe, and his later transformation of matter into a manifestation of powers was in effect a synthesis of Baxter's matter and spirit, as it was in Michell's. Whether or not he had read Baxter by the time he wrote the Institutes, Priestley's interest in "powers" and his belief in their metaphysical grounding is clear in this work, as is his distinction between matter and immaterial spirit.

Although God was for Priestley an immaterial spirit he acted upon the material universe constantly:

> The divine being, knowing all things, and exerting his influence on all the works of his hands, whereby he supports the existence of every thing that he has made, and maintains the laws which he has established in nature, must be, in a proper sense of the term, omnipresent. For, tho' being a spirit, he can have no proper relation to place, and much less to one particular place more than another (which is a property of spirit of which we can have no adequate conception) he must have a power of acting every where, to which the idea belonging to omnipresence is sufficiently applicable.[14]

Priestley here assumed that matter and spirit had no properties in common and hence spirit could have no relation to space, yet alone to matter. Yet God possessed the "power of acting every where," which to Priestley signified omnipresence. Although he did not say so specifically, his statement seems to imply that the laws and powers of nature created and maintained by God were the agents whereby God governed the universe. Such an interpretation would render the laws and powers the means of reconciling the gulf between matter and spirit.

God utilizes the powers of nature to organize the matter of the universe, according to Priestley's view. The Epicurean concept of the "fortuitous concourse of atoms" producing the universe lacked any effective agency, he argued:

> They could, of themselves, have had no power of acting upon one another, as bodies now have, by such properties as magnetism, electicity, gravitation, &c. unless these powers had been communicated to them by some superior being.[15]

Priestley neither explicitly accepted or rejected the notion of "atoms" in this work. Bodies, he said, acted upon one another by at least three powers of nature which were properties of bodies, namely magnetism, gravity and electricity; if atoms possessed such powers as properties, they could only have done so if these had been communicated to them by God. Powers whereby atoms and/or bodies acted upon one another were essential to the existence of the universe, in Priestley's opinion, and no mere "fortuitous concourse of atoms" could suffice to that end.

Priestley thus mentioned six possible properties of matter, including five powers. To the property of extension he added the powers of magnetism, electricity and gravitation, and suggested that perception and intelligence were perhaps somehow "superadded" to matter.

From his definition of power as that whereby substances act upon one another, one can also speak of perception and intelligence as powers of mind, it would seem to me, for they are that by which the mind operates upon and controls the body. This concept seems analogous to Priestley's statement elsewhere in the Institutes

> ...that thinking and acting, or creating, may be the same thing with God.[16]

If for God thinking and acting are identical processes, and if, as Priestley argued, God thinks of and acts upon the universe through powers; the thoughts and actions (or powers) whereby man governs his own body and interacts with the world can be thought of as finite and created analogues of the mind of God. They depend completely upon God for their existence. The powers of mind distinguish it from other, simpler matter. Man uses his mental powers

to think about the world, and his physical powers to implement the decisions his mind makes, in a manner analogous to the way in which God uses his powers to organize the universe.

Priestley discussed natural religion and its relation to revealed religion, and also briefly outlined his views on human immortality, the nature of the human mind and of matter.

He defined precisely the realm of natural religion, placing

> ...under the head of natural religion, all that can be demonstrated, or proved to be true by natural reason, though it was never, in fact, discovered by it; and even though it be probable that mankind would never have known it without the assistance of revelation.[17]

Natural religion thus included all those truths demonstrable by the use of "natural reason", that faculty whereby man reasons about the created or "natural" universe and its laws. A doctrine, such as that of a future state, to cite Priestley's example,

> ...may be called a doctrine of natural religion, if when we have had the first knowledge of it from divine revelation, we can afterwards show that the expectation of it was probable from the light of nature, and that present appearances are, upon the whole, favourable to the supposition of it.[18]

Priestley argued that the "doctrine of a future state" was a doctrine of natural religion.[19] He said that God's moral government of the world, and proof of a general belief in the doctrine of life after death which would show it to be a traditional belief, would constitute evidence of its truth. Another argument was based on nature and God's omnipotence:

> Admitting that death is an intire cessation of thought, similar to a state of perfectly sound sleep, or a stupor, yet, if the purposes of God's providence require it, he can make us to awake from this sleep at any distance of time; and then the interval, let it have been ever so long, will appear as nothing to us.[20]

Thus although nothing in nature could have led man unaided to a belief in a future state, God's revelation of it led men to find a natural analogy in sleep. Priestley accordingly placed the doctrine

of life after death in the realm of natural religion, for though it was explicitly revealed, and also supported by knowledge of God and by historical tradition, nature also provided an analogy to the "sleep of the soul" after death in the form of natural sleep. As Priestley's growing materialism led him to reject the immortality of the soul and finally to deny the very existence of the soul itself, the "sleep of the soul" and the argument from nature disappeared from his defence of immortality. But for the moment Priestley accepted the immateriality of mind or "spirit", while matter remained sluggish and inert.

In summary Priestley conceived of God as immaterial, acting through the powers of nature to execute his laws in the universe, and suspending these laws on occasion to reveal miraculously some truth not otherwise readily known to man through nature or biblical revelation. The resurrection of the dead was not miraculous in that sense for the"sleep of the soul" had a natural analogue in sleep, and was thus a doctrine of natural religion.

The "doctrine of a future state" was a major issue in Priestley's views on epistemology, psychology and metaphysics in the mid-1770's, particularly in relation to the immateriality of the mind and the immortality of the soul. In the work we have been examining he rejected the immateriality of the mind even though he conceived of matter as passive, while at the same time he accepted immortality as a doctrine of natural religion, though he soon rejected any defense of the latter concept from nature or reason and based it solely on biblical revelation.

Priestley regarded the nature of substance as unknowable except for its inability to move itself or to generate the universe. Only God could move himself, and acting through the powers of nature could generate the universe. Matter appeared to Priestley

in this work to be passive, though he spoke of bodies possessing powers of gravitation, electricity and magnetism, and of the possibility of powers of perception and intelligence being "superadded" to it. However, as was shown in chapter four, his observation of the attractive and repulsive powers of matter by the time he published the History of Optics led him to posit the identity of matter and its powers.

(11)

The next major stage in Priestley's thinking on man's knowledge of substance and its properties was shown in An Examination of Dr. Reid's Inquiry into the Human Mind on the Principle of Common Sense, Dr. Beattie's Essay on the Nature and Immutability of Truth, and Dr. Oswald's Appeal to Common Sense in Behalf of Religion (London, 1774). Here Priestley defended Locke and Hartley's view of human nature against the "common sense" philosophers,[21] and in so doing outlined his own epistimology which owed much to both Locke and Hartley. Priestley posited implicitly a parallel between the association of ideas about a substance and its properties, and the actual relationship between a substance and its properties. Although the principle of psychological association thereby gave Priestley an idea which he could use in explaining the relationship between substance and its properties, it did not, as he recognized, give any certain knowledge about the nature of substance itself.

Priestley attacked four aspects of the "common sense" philosophy: its rejection of psychological association as the generating principle of ideas; its reintroduction of instinctive principles; its rejection of Lockean scepticism concerning the possibility of certain knowledge about substance and God; and its absolute and uncritical acceptance of the reality of the external world.

In the "Introductory Observations" Priestley described his own view of the genesis of ideas concerning external objects and their properties, basing his interpretation on Locke's description of our complex ideas concerning substance,[22] and on Hartley's theory of psychological association and his mechanical description of the process of perception. When one first sees an object, according to Priestley, one perceives all its constituent parts and properties.[23] An impression on the senses is the result of the object's being placed where one can perceive it, and this leads to an impression on the mind, or a perception.

Priestley noted that the various images which constitute an entire impression were associated with one another in so connected a fashion that the recollection of the idea of any single part or property of the impression led by psychological association to the recollection of the idea of the other parts associated with it, and hence to a recollection of the entire idea of the object. Priestley thought that this initially selective recollection enabled the mind to distinguish the essential from the non-essential properties of the idea of the object.

In this manner association led to a recognition of the properties of an idea, and Priestley continued, using Locke's examples:

> The idea of any thing, and of its necessary inseparable properties, as those of <u>milk</u> and <u>whiteness</u>, <u>gold</u> and <u>yellow</u>, always occurring together, is the foundation of, and supplies the materials for <u>propositions</u>, in which they are affirmed of one another, and are <u>said</u> to be inseparable....[24]

Because the idea of the substance gold brought with it the idea of the colour yellow, one spoke of the yellowness as a necessary and inseparable property of gold, a property without which gold was not gold. One could construct a proposition using a substance as subject and the property as predicate based on observation of the constant recurrence of association of substance and property in the mind and in observed reality. A proposition was for Priestley a universal truth with a necessary connection existing between subject and predicate, substance and property.

Priestley discussed further the relationship between gold and its properties:

> Also, since wherever there has been the specific gravity, ductility, and other properties of gold, the colour has always been yellow, we conclude that those circumstances are necessarily united, though by some unknown bond of union, and that they will always go together.[25]

Two properties of gold were added to yellowness, namely specific gravity and ductility, two physical properties which helped distinguish gold from other substances. One concluded from always observing this substance to be yellow that the property of yellowness was "necessarily united" to the substance, even though the nature of that union was "unknown". Priestley implied that one could not know why gold was yellow; but his use of the phrase "necessarily united" suggests that he believed that something in the nature of gold produced the perceptible property of yellowness, though the reason for this was unknown. He described the union as "necessary", namely following some law of nature, rather than "arbitrary" in the sense of obeying no fixed laws, perhaps reflecting his belief in the rationality and lawfulness of the Creator and his universe.

It is interesting that Priestley displayed such scepticism concerning the connection between gold and its yellowness, its specific gravity and its ductility, for the History of Optics

showed how all three properties could be explained by reference to theory of matter. All three properties resulted from particle structure and/or powers of matter. Specific gravity could be determined by the density of particles; ductility by the strength of the attractive powers holding together the particles; and colour was produced, in Michell's "doctrine of attractions and repulsions", by the interaction of the powers of the several planes at the surfaces of a body. The explanation of Priestley's scepticism concerning the nature of the union between gold and its various properties is perhaps that even an understanding of the activity of those powers and particles which constitute what we term "gold", does not indicate what gold really is or how it came to be gold. Priestley believed the nature of substance to be unknowable, so that even his work in optics and electricity, revealing much about its properties and powers, did not reveal anything about what matter "really" was, for that question did not signify anything to him.

Priestley distinguished between propositions which were products of "art" (man's doing), and the connections in nature which they described.[26] Propositions signified "mental operations", the observation of which was essential to an understanding of our conception of "truth":

> ...just as other theories are deduced from facts previously known; so the doctrine of propositions and judgment was deduced from observations on the coincidence of ideas, which took place antecedent to any knowledge of that kind.[27]

Knowledge of the world was gained from reflection on sense impressions, according to Priestley, once again echoing Locke and Hartley. The sentient being noted that the objects of his thought did not exist in the sense organs but in the brain:

> This kind of knowledge is gained by observation and experiment, as much as the theory of the eye and of light, though we

> ourselves are the subject of the observations and experiments. And our thinking and acting, in the conduct of life, is as much independent of this branch of knowledge, as the powers of air and light are independent of our knowledge of them.[29]

The difference between things and the thought of things led some people to conclude that thought was independent of the external world. Berkeley, for example, supposed that God impressed sensoria directly to create the idea of an external world, and though Priestley thought this an unlikely hypothesis he granted that it was a possibility. He thought it more reasonable, however, to suppose the existence of an external world,

> ...by means of which, and a more general agency of the deity than Bishop Berkley supposes, all our minds are necessarily impressed in this corresponding manner.[30]

Such an explanation invoked a simple and general principle whereby a single cause (the external world) produced a single common effect (the idea of an external world) in all men by the one act of the Deity in creating an external world. This hypothesis explained the role of God in creating the impression of an external world without invoking his agency in the creation of the idea of that world in each individual mind. It thus harmonized with Priestley's belief in God's general non-interruption of the laws and phenomena of nature, and harmonized with Newton's principle of the simplest causal explanation.

(111)

Priestley's first extensive application of the monistic and dynamic theory of matter which he adopted from Michell came in his abridgment of David Hartley's 1749 Observations on Man, which Priestley published in 1775 under the title of Hartley's Theory of the Human Mind, on the Principle of the Association of Ideas; With Essays Relating to the Subject of It, (London, 1775).

In his introductory essays to the work Priestley used Hartley's principle of association of ideas in conjunction with a mechanical theory of perception, a physical theory of the mind, and a dynamic theory of the powers of matter to explain mental phenomena. Explaining mental activity by reference to physical properties of the brain (using Michell's principle of the ascribing of properties to substance) he expanded on Locke's concept of thought being superadded to matter, adding to that concept the idea of mental powers dynamically related to the substance of the brain.

Priestley thought that Hartley's associationist psychology had been neglected because of the"system of moral and religious knowledge" in which it had been placed, and felt that the theory of vibrations and the physiological evidence which Hartley had included increased the difficulty of the work.[31] Though Priestley personally accepted the arguments in the Observations apart from the mind-body dualism, his abridgment omitted these "difficult" sections, and presented Hartley's associationist psychology, reserving the moral and theological sections for possible later publication.

In the Institutes, volume i, Priestley had taken seriously Locke's suggestion that powers of perception and intelligence could be somehow superadded to the brain, but in these essays he

applied this notion rigorously, and explioitly rejected Hartley's dualist position, regarding the use of an immaterial prinoiple to explain thought as a oonfession of ignorance.

Matter and spirit, he said,

> ...are always desoribed as having not one common property, by means of whioh they can affect or aot upon eaoh other; the one ocoupying space, and the other not only not ocoupying the least imaginable portion of spaoe, but incapable of bearing relation to it; insomuch that, properly speaking, my mind is no more <u>in my body</u>, than it is in the moon.[32]

Priestley assumed matter and immaterial substanoe to have no oommon properties whereby they could have any relation to each other and act on eaoh other. He had spoken in the <u>Institutes</u> of the "power of aoting upon one another"[33] as the necessary condition for the interaotion of substances; and a rigorous definition of immaterial substanoe as not matter, as that whioh shared no common properties with matter, made any mutual action impossible.

In his definition, a substance was that whioh supported properties, and a power was that aotivity whereby one substance acted on another; to speak of an immaterial power would imply an immaterial body's acting upon a material substanoe, which he regarded as impossible. In the introduotory essays he applied this definition to the question of mind-body dualism, advanoing a materialist, monist position; and his belief in the impossibility of material-immaterial interaction ultimately led Priestley to the fully materialist metaphysio elaborated two years later in the <u>Disquisitions Relating to Matter and Spirit</u>.

Priestley stated

> ...that the whole man is of some <u>uniform composition</u>, and that the property of <u>perception</u>, as well as the other powers that are termed <u>mental</u>, is the result (whether necessary or not) of such an organical struoture as that of the brain.[34]

By assuming mind and body to be "of some uniform oomposition" Priestley asoribed to man a single substance, attributing the

properties and powers of the mind to the organical structure of the brain, though he was apparently unsure whether these powers were the necessary (namely, always occuring) result of such a structure, or only a possible result.

For Priestley this materialist view implied

> ...that the whole man becomes extinct at death, and that we have no hope of surviving the grave but what is derived from the scheme of revelation.[35]

He rejected the "sleep of the soul" which he had implicitly accepted in the Institutes[36] in favour of the death of the entire man when the body died. Whereas the sleep of the soul and the resurrection of the dead were described as part of natural religion in the Institutes (as well as being revealed truth), Priestley now dismissed the former, and based the latter on (Biblical) revelation alone. The other major difference between Priestley's views in these two works was the replacement of sluggish and inert matter by dynamic and penetrable matter. In the Institutes he had proposed ascribing mental powers to the former; here he attributed mental powers to a material substance itself consisting of powers.

Thus the physical basis of the psychological theory advanced by Priestley was dynamic. He now explicitly introduced the idea of penetrable matter consisting of powers,[37] combining it with the Lockean idea that matter may be endowed with mental powers, and with Michell's epistemology in which matter could have ascribed to it any properties which helped explain phenomena.

Priestley accepted Hartley's theory of "vibrations" as the mechanism whereby the sense organs received impressions from external objects and transmitted those impressions to the brain. Hartley had argued that minute particles in the sense organs were set in vibratory motion by the impression of external objects, this vibratory motion then being communicated to other particles in

the nervous system and ultimately to the brain by a subtle etherial fluid which filled the nervous system.

Priestley thought that Hartley had established the doctrine of vibrations on sound physiological evidence, but he felt that the doctrine was a source of difficulty in Hartley's theory and accordingly omitted much of Hartley's discussion from his abridgment.[38] He argued that the doctrine was not essential to Hartley's theory, which position ignored Hartley's concern for the physical and physiological basis of his theory, and contradicted his own materialist theory of the mind.[39]

Hartley had derived the concept of vibrations from Newton,[40] who proposed vibrations in an aetherial substance filling the nerves as the cause of sensation (at the end of the Principia);[41] while Query 12 of the Opticks concerned rays of light generating vibrations in the tunica retina, the resulting vibrations being transmitted to the brain; and Query 13 concerned different rays making different-sized vibrations and producing the sensation of various colours.[42] Hartley constructed his system on Newton's concept of vibrations and on the aether, with vibrations transmitted to the brain producing ideas of sense, and the mechanical association of sense ideas producing complex ideas through the medium of vibrations of very small particles in the nervous system.

Priestley nonetheless defended Hartley's theory of vibrations, citing the repulsive powers of matter in his argument:

> Now that the nerves may be of a constitution that will admit of this cannot be denied, though the structure which this purpose requires be ever so exquisite; especially when it is considered that all bodies whatever do actually possess this very property, in a greater or less degree, in consequence of their constituent particles not being in actual contact with each other, but kept at a certain distance from one another, by a repulsive power.[43]

The particles of all bodies were capable of vibration because

their repulsive powers kept them apart, and this separation permitted motion. Neither Newton nor Hartley had used repulsive powers explicitly to explain the distance between particles, and both had assumed an aether as the means whereby motion was transmitted from particle to particle. Priestley on the other hand applied the concept of repulsive powers, central to his and Michell's theories of matter, to explain the distances and the possibility of vibratory motion, and omitted the aether, presumably because it was not necessary to his hypothesis.

Priestley implied a conception of particles arranged in various patterns in different substances but all capable of some vibratory motion however closely packed; being incapable of actual contact they could not be looked motionless in a specific location by surrounding particles.

Priestley argued only for the possibility of vibrations in the nervous system and the brain. Natural philosophers, he said, had become

> ...acquainted with the more subtle and important laws of matter exhibited in chymical operations; so now that we see that the laws and affections of mere matter are infinitely more complex than we had imagined, we may, by this time, I should think, be prepared to admit the <u>possibility</u> of a mass of matter like the brain, having been formed by the almighty creator, with such exquisite powers, with respect to vibrations, as should be sufficient for all the purposes above mentioned; though the particulars of its constitution, and mode of affection, may far exceed our comprehension. And it is only the bare <u>possibility</u> of the thing that I now contend for.[44]

Priestley thus only asked the reader to admit the possibility that the brain possessed mental powers sufficiently responsive to vibrations to permit the processes of thought.

Granting only the theory of vibrations and the attribution of perception to the matter of the brain, Priestley thought that immateriality could be abolished from mind, and that Hartley's

doctrine of association would be helped by so doing.[45] Those who used the immateriality of the soul to defend a future life objected to materiality, but Priestley based his belief in life after death "on the christian doctrine of a resurrection from the dead,"[46] and on that alone.

Priestley's attribution of thought to the same material substance which constituted the body harmonized with Michell's principle that any property (in this case the power of perception) assigned to a substance (mind) must help to explain a phenomenon (thought). Michell's other contributions to Priestley's theory were the concept of repulsive powers as a substitute for the aether in explaining vibrations, and his theory of penetrable and dynamic matter which nullified the immaterialist objection (supported by Priestley himself in the Institutes) that matter was sluggish and passive, and hence incapable of supporting an active process such as thought.

Despite the dynamic nature of his theory of matter Priestley did not think matter capable of self-motion, for no created substance had that power;[47] but Hartley had supposed that the initial stimulus leading to perception came through the impression of the sense organs by external objects, so that one did not need to suppose matter to be self-moving for it to be able to support perception and thought.

Priestley did not explain why dynamic material substance was better able to support thought than "sluggish" and "inert" matter, though his reasoning was suggested in his description of thought as a "power".[48] If one considered matter as passive and only capable of being acted upon because it had no powers of its own, then one necessarily supposed a dynamic (and hence immaterial) power to activate it, whether explaining the motion of particles

and bodies or the activity of mind. If on the other hand one attributed to matter such powers as attraction and repulsion, the possibility emerged of attributing a further power such as thought to matter. Ascribing the power of thought to a substance possessing no other active powers might seem arbitrary, but Priestley had already ascribed physical powers to matter, and hereby added another, though more complex, mental power to matter when he said it might be able to support thought.

It is worth noting that Priestley did not say that matter could think, but only that it might be able to support thought. Further, he did not say that all matter could support thought, but only that the organized structure of the brain might be able to do so. All matter possessed powers of attraction and repulsion, and the organized material structure of the brain (an aggregate of matter) accordingly possessed the power of thought. (The brain is of course part of a living organism though Priestley did not discuss this.) He argued that the structure of the nervous system and the brain permitted vibrations whereby sense impressions were transmitted to the brain; there the vibrations of particles in various directions and combinations produced associations of sense ideas,[49] whence, as Hartley argued, all simple and complex ideas were developed.

The whole system seemed complete without the addition of any "power" of thought to the brain; yet Priestley's attribution of this additional power to the brain suggests his awareness of the difficulty of explaining mental processes by mere physical powers of matter. He granted neither the immateriality nor the natural immortality of any part of man, nor the self-motion of the mind, but would not admit thought to be merely a produot of the powers of matter. He found dynamio penetrable matter with

its powers of attraction and repulsion compatible with the power of thought, but not all matter possessed the power of thought, which was a separate and distinct power of the material substance of the brain.

Priestley's transformation of matter into a manifestation of powers along the lines proposed by Michell left it no longer the passive substance which immaterialists had found unsuitable for the support of thought. Although he had formulated his dynamic theory of matter in the History of Optics, it was only in the introductory essays to Hartley's Theory that he applied Michell's views on matter and powers to transform Hartley's associationist psychology into a completely monist and materialist system by attributing to the organized matter of the brain the additional power of thought.

(iv)

In 1777 Priestley published Disquisitions Relating to Matter and Spirit, To which is added, the history of the philosophical doctrine concerning the origin of the soul, and the nature of matter; with its influence on christianity, especially with respect to the doctrine of the pre-existence of Christ. In the Disquisitions and the appended sequel he presented a detailed explication of the monistic metaphysical system he had constructed on the basis of Michell's synthesis of matter and spirit.

He extended his argument for the materialism of mind; argued that man was of a single material substance and completely mortal; and dismissed immaterial mind and soul as unnecessary, unphilosophical and "modern" ooncepts, unknown in the Scriptures. He advanced the "humanitarian" argument that Christ was nothing more than a man, and argued that God, whom he believed to be unitary in nature, might possibly be a material being. He linked his and Michell's dynamio theory of matter to a "materialist" psychology and metaphysic, and these to the "humanitarian" description of Christ and the possible corporeal nature of God.

In the sequel to the Disquisitions Priestley compared Christian doctrines with the concepts of classical Greek philosophy and oriental religions in order to explicate the origin and significance of Christian thought. The establishment of the truly Christian nature of his metaphysical speculations occupied much of the Disquisitions and its sequel, and was of the greatest importance to him, and he used comparative techniques to try to determine what Christian revelation taught, once extraneous philosophical and religious concepts had been removed. There was an implicit faith that the findings of modern natural philosophy (particularly concerning the nature of matter) and the metaphysical speculations built on those findings, would harmonize with the "true" Christian revelation.

It was this belief that led Priestley to discuss once again his concepts of matter and powers, and then to apply the monism, the theory of penetrable matter and powers, and the principle for attributing properties to substance which he had adopted principally from Michell, to man's whole frame, and to the nature of Christ and of God.

Firstly let us look at Priestley's discussion of matter and

its powers in the Disquisitions. He described again the phenomena of repulsion which he had discussed in the History of Electricity, declaring that this sort of phenomenon led to the conclusion

> ...that resistance, on which alone our opinion concerning the solidity or impenetrability of matter is founded, is never occasioned by solid matter, but by something of a very different nature, viz. a power of repulsion always acting at a real, and in general an assignable distance from what we call the body itself.[50]

Thus surface repulsive powers rather than the body itself caused resistance to penetrability.

The shape and form of bodies were the result of some mutual attraction which held the constituent parts in place

> ...so as either to keep contiguous to, or preserve a certain distance from each other.[51]

Priestley implied the possibility of contiguity (or immediate contact) between particles, which his chemical work may have suggested, but which appears to have contradicted his theory of matter. Presumably the innermost repulsive powers were counterbalanced by the attractive powers of the other particles, so that contiguity could be established without compenetration occuring.

Priestley maintained that the power of attraction must be essential to the

> ...actual existence of all matter; since no substance can retain any form without it.[52]

Attraction and repulsion were powers

> ...which I make to be essential to the being of matter, and without which it cannot exist as a material substance at all....[53]

Michell's position that a substance was located where its properties were did not say what matter was, only where it was located. Priestley noted that "substance" was a term used to refer to something unknowable to which one supposed the powers and properties to belong.[54]

Priestley went farther than those who spoke of properties or powers "inhering" in matter. For him attraction did not "inhere" in matter; it was rather a power which constituted matter.

From the ability of light to pass through even the densest transparent bodies Priestley concluded that these substances had no resisting particles:

> All the phenomena may be explained without them, and indeed cannot be explained with them.[55]

If a power of repulsion prevented actual contact

> ...there can be no sufficient reason to ascribe resistance in any case to any thing besides similar powers.[56]

Both the physical evidence and Newton's rule of ascribing to effects the fewest possible causes, he said,

> ...require that we ascribe all resistance to such powers; and consequently the supposition of the solidity or impenetrability of matter, derived solely from the consideration of the resistance of the solid parts of bodies (which, exclusive of a power operating at a distance from them, cannot be proved to have any resistance) appears to be destitute of all support whatever.[57]

Matter for Priestley possessed the properties which appearances proved it to have:

> That it is possessed of powers of attraction and repulsion, and of several spheres of them, one within another, I know; because appearances cannot be explained without supposing them; but that there is any thing in, or belonging to matter, capable of resistance, besides those powers of repulsion, does not appear from any phenomena that we are yet acquainted with; and, therefore, as a philosopher, I am not authorized to conclude that any such a thing exists.[58]

Priestley had adopted Locke and Newton's scepticism concerning certain knowledge of substances, and although this claim about attraction appears to contradict that position, Priestley was not claiming to state what matter really was. He only said, in effect, that to explain appearances (a body with form or shape) one must attribute a property (the power of attraction) to the matter of which the body consisted.

Yet these powers were neither self-existent nor capable of self-motion:

> ...from whatever source these powers are derived, or by whatever being they are communicated, matter cannot exist without them; and if that superior power, or being, withdraw its influence, the substance itself necessarily ceases to exist, or is annihilated.[59]

The powers were derived from the agency of a superior power (God), but were not themselves agencies of God. Priestley maintained that the strict immaterialist argument of Baxter, that the powers activating matter were the immediate agency of God, led inevitably to the conclusion

> ...that there is not in nature any such thing as matter, distinct from the Deity, and his operations. A strange opinion, but that in which Mr. Baxter's hypothesis necessarily terminates; though, since he was not apprized of it, it ought not to be imputed to him.[60]

Priestley believed it more philosophical to ascribe the effect produced by a substance to its powers rather than immediately to God. In this way the Deity alone preserved a substance rather than

> ...by his immediate agency, performing all that we ascribe to that substance; which is in effect to annihilate the substance, and to make the Deity himself to do, and to be every thing.[61]

Thus God created and preserved the powers, and through them matter, rather than being himself the powers. Priestley rejected Baxter's "immaterialism" on grounds very similar to those on which he rejected Berkeley's "immaterialism". In Priestley's opinion, the former supposed God to be the universe which we see, matter having no independent existence; the latter supposed that God created the impression of the external world, matter and the external world having no real existence.

Priestley's "immaterialism", unlike Baxter's, assumed the powers of matter to be preserved by God, but not themselves immediate agencies of God; and unlike Berkeley's, it assumed the existence

of an external world as the simplest hypothesis to explain our perceptions.

Nonetheless, Priestley recognized that his definition of matter posed a difficult problem, namely:

> ...how, upon this hypothesis matter differs from spirit, if there be nothing in matter that is properly solid or impenetrable;[62]

to which he responded:

> ...it no way concerns me, or true philosophy, to maintain that there is any such difference between them as has hitherto been supposed.[63]

Priestley had maintained that the interaction of substances required the existence of at least one common property:

> ...I consider the notion of the union and mutual influences of substances so essentially different from one another, as material and immaterial substances have been represented, as an opinion attended with difficulties infinitely embarrassing, and indeed actually insuperable....[64]

Priestley said that Newton had implied that there was so much void space in bodies

> ...that for any thing we know to the contrary, all the solid matter in the solar system might be contained within a nutshell....[65]

Priestley thought that the conclusion to be drawn from this was obvious, even if other philosophers had not recognized it:

> Now when solidity had apparently so very little to do in the system, it is really a wonder that it did not occur to philosophers sooner, that perhaps there might be nothing for it to do at all, and that there might be no such a thing in nature.[66]

Priestley clearly saw Michell's work and his own as a logical conclusion to Newton's work, and placed his "immaterialist" theory of matter in the Newtonian tradition. Both Newton's theory of matter and the void, and his rule of the fewest possible causes, led in Priestley's opinion to the conclusion that matter was nothing but powers, and possessed no extension or solidity; and all the phenomena in nature could thus be explained by the activity

of those powers.

Let us next look at Priestley's discussion of the nature, properties and powers of mind. He argued on the basis of Michell's criteria for ascribing properties that matter could be supposed to possess the powers of thought

> ...till it can be shewn that these powers are incompatible with other known properties of the same substance; and for this I see no sort of pretence.[67]

Newton's principle of the fewest possible causes implied for him that

> If one kind of substance be capable of supporting all the known properties of man; that is, if those properties have nothing in them that is absolutely incompatible with one another, we shall be obliged to conclude (unless we openly violate the rules of philosophizing) that no other kind of substance enters into his composition; the supposition being manifestly unnecessary, in order to account for any appearance whatever.[68]

Priestley clearly thought that man, as substance, could have attributed to him any powers or properties not incompatible with one another, and able to explain phenomena, as Michell had reasoned concerning substance. Further, if supposition of a single substance could explain those properties and powers, man must be supposed to be of a single substance.

Priestley noted

> ...the powers of sensation or perception, and thought, as belonging to man, have never been found but in conjunction with a certain organized system of matter; and therefore... those powers necessarily exist in, and depend upon, such a system.[69]

The mental powers were accordingly properties of the brain, for these powers

> ...and a certain state of the brain, always accompany and correspond to one another; which is the very reason why we believe that any property is inherent in any substance whatever.[70]

Priestley stressed the close relation between mind and body observed in the maturation of both, in the frequent decay of both in old

age, in the impairment of the mental faculties caused by an injury to the brain, and in the effect on the body of strong passions originating in the mind.[71] From these considerations it appeared evident to him that the brain was indeed "the seat of the SENTIENT PRINCIPLE",[72] and that the brain and mind affected the body and were affected by it. By Priestley's principle of interaction of substances, the mind and body therefore had at least one property in common.

Priestley had already maintained that the mental powers were properties of an organized system of matter, the brain;and he had stated in the Institutes, volume i, that matter could have powers of thought superadded to it. In Hartley's Theory he had supposed matter to possess powers of attraction and repulsion to which mental powers could be added. In the present work he made more explicit and complete his argument: the brain was the seat of the mind; the mind interacted with the body; and the brain and mind depended on the body for existence. He arrived at the monistic position that "one kind of substance" was as he hoped to show, "...capable of supporting all the known properties of man...."[73] Priestley found nothing in the Scriptures denying the materiality of man, and argued that if man had consisted of two parts as different as matter and spirit, with matter subservient to spirit, there 'might',he said,have been some specific mention of this fact

> ...in the Scriptures, which contain the history of the creation, mortality, and resurrection of man.[74]

He found instead "a most remarkable silence" on the subject, and "many things...which unavoidably lead us to form a different conclusion," with only "a few passages ill translated, or ill understood" which contradicted "the uniform tenor of the rest."[75]

Priestley regarded mind as not only material, but mortal

as well.[76] He reasoned that if it were immaterial and immortal, its individual faculties would also be so; but each faculty could in fact become impaired or extinct before death. It followed from the mortality of each property of the mind that the substance itself, mind, was mortal as well. Similarly the possible decay and even extinction of the senses before death showed clearly the mortality of the body.

If one defended the immateriality of the sentient principle, it followed that it must be simple, indivisible, and without extension. Further,

> ...if the substance of the soul was not simple and indivisible, it would be liable to corruption, and death; and therefore... no advantage would be gained by supposing the power of thinking to belong to any substance distinct from the body.[77]

However, if the soul was immortal and retained ideas after separation from the body, the ideas had been produced by external objects and hence necessarily consisted of parts, as the objects themselves did.[78] Priestley drew this conclusion on the basis of a sensationalist psychology, without taking into account the possibility of innate ideas. His own psychology led him nonetheless to say that ideas had parts, and that the soul, therefore, possessing parts and their concomitant, extension,

> ...cannot be that simple, indivisible, and immaterial substance that some have imagined it to be; but something that has real extension, and therefore may have the other properties of matter.[79]

Priestley discussed Baxter's argument that the soul could not become diseased, mad, or in any way disordered, because it had no parts.[80] But, Priestley asked,how then could God possibly punish or reward the soul after death, if the destruction of its link with the body was sufficient to remove from it all its vices? Although Priestley did not accept the existence of an immaterial soul, he believed in the bodily resurrection of the dead and their

punishment or reward by God after the resurrection. He objected to Baxter's idea of a separate and incorruptible soul, which suggested as its concomitant the natural corruptibility of the material body, a notion to which Priestley attributed the low esteem in which matter had been held.[81]

Priestley attributed the origins of the concept of the soul to a tendency to explain complicated phenomena such as life by the activity of an "invisible agent".[82] From this explanatory system developed the idea of madmen being possessed by demons or spirits. Similarly noxious fumes of a fermenting liquor were called a "gas" or "spirit" of that substance; the liquor itself, possessing "very active powers", was also thought to contain a type of "spirit".[83] Priestley noted from his own experience that some people ascribed remarkable phenomena in experiments, particularly those involving air or other gases, to the action of the "spirit" of the gas.

Similarly, he argued, the source of thought had been attributed to that which most readily distinguished living from dead persons, namely the breath; and in Hebrew, Greek and Latin the words for "breath" and "soul" were identical which implied to him an equivalence of the two concepts in those languages.[84] The "soul" or "breath" was supposed to be something distinct from the air into which it departed at death, and being very light, it ascended into the heavens, whence it was supposed to have descended originally. This, Priestley argued, was the origin of the doctrine of the pre-existence and the transmigration of souls.

In contrast, the diseases which troubled man occurred in the body, and that substance of which the body was constructed could easily come to be thought of as evil. Matter could be looked upon as evil "without reflecting any blame upon God on that account".[85]

What more fitting punishment for a miscreant pre-existing soul than to be confined to a material body? Although his contemporaries did not accept the concept of the pre-existence of souls, the notion of the "contagion of matter", which Baxter specifically used, was a survival of that earlier doctrine.[86]

Priestley thought that the concept of immaterial spirit as his contemporaries understood it, was not a traditional belief, the ancients having meant by immaterial

> ...nothing more than an attenuated matter, like air, ether, fire, or light, considered as fluids, beyond which their idea of incorporeity did not go.[87]

Priestley, as we have seen, defended the materiality of the electric "fire", of light, and of "airs"; and he here claimed that the ancient concept of immaterial substance was that of "attenuated matter", which was virtually identical with his idea of those substances. The ancient and "unphilosophical" conception of these substances was thus remarkably similar to his much more "philosophical" conclusions on the subject.

The ancients' concept of an immaterial soul was very different from that of contemporary metaphysicians, Priestley thought. The latter had realized

> ...that if the powers of sensation or thought could belong to such a material substance as the ancients had denominated an immaterialone (being only an attenuated kind of matter) it might be imparted to the very grossest matter; since it is naturally capable of the same attenuation; and therefore, that the soul and body, being in reality the same kind of substance, must die together.[88]

They had thereupon redefined immaterial substance in such a way that it could not possibly have any affect on matter, having no properties in common with it, with concepts such as Descartes' "occasion" and Leibniz's "pre-established harmony" being to him examples of how philosophers tried to bridge this otherwise irreconcilable gap between matter and spirit.[89] His own "immaterialist"

materialism, he thought, made unnecessary any such attempts to reconcile the two.

Let us see how Priestley's dynamic and monistic theory of substance affected his religious beliefs. His rejection of the immateriality, immortality, and pre-existence of souls had a profound effect on his beliefs concerning both Christ and God the Father. He had by this time become a unitarian, and believed in the mere humanity of Christ. As he later noted in his defence of the humanity of Christ, his recognition of the material nature of man could provide an important part of that argument.[90] He said in the Disquisitions that Christ was regarded as a mere man by his disciples, though a man high in the esteem of God, and with tasks appointed by God.[91] Believing as he did that man was material and mortal, it was reasonable to assume that Christ, too, was material and mortal.

He maintained in the Disquisitions that the doctrine of the pre-existence of souls had been applied by Christian apologists to the nature of Christ, leading away from the acceptance of his humanity by the men who knew him best, to the notion that he had a higher rank than other men before birth.[92] Some called him creator of the world, under God (the Arian hypothesis); he became for others an emanation of the divine essence (neo-Platonism); and trinitarianism ascribed to him co-equality with God the Father through all eternity. Priestley's historical defence of Christ's humanity (and the unity of God) was thus closely linked to his rejection of the pre-existence of souls as pagan and pantheistic, and of the immateriality of souls (as maintained by his contemporaries) as both unphilosophical and historically unjustified.

In the extension of his system of materialism Priestley argued that God himself, though creator of the world, and a being of

infinite wisdom, power and goodness, might be a material being. He recognized the extreme audacity of his position, the sensitive nature of the issue, and the great ignorance one must necessarily have on the subject, but would not on that account

> ...decline speaking freely and fully to every difficulty that either has been urged against the system of the materiality of man, or that has occurred to myself with respect to it....[93]

Just as one knew nothing about matter beyond the powers it possessed,

> ...much less can our ideas go beyond powers, properties, or attributes, with respect to the divine Being....[94]

One deduced the powers and attributes of God from his works, (a position similar to Michell's on the powers and properties of substance), and they seemed on that account infinitely superior to those of the human minds where some analogy existed; and where no analogy existed, these powers and attributes were essentially so different that the use of the same terms would have been inaccurate.

Perhaps the most notable property of God was his omnipotence:

> For since all that we know of bodies, are their powers, and the divine Being changes those powers at pleasure, it is evident that he can take them all away, and consequently annihilate the very substance; for without powers, substance is nothing.[95]

Thus the nature of God and his powers was essentially different from human nature,

> ...and consequently no common term except such comprehensive terms as <u>being</u>, <u>nature</u>, &c. can be properly used to express them both.[96]

There was no evidence to suggest that God possessed properties common to other substances even though Priestley thought a common property was necessary for any substance to act on another. One could not, Priestley noted, perceive God's presence as one could that of matter, even though God had to be and act everywhere in preserving the universe. The nature of God was accordingly not

only unknown to man, as was every essence, but had some properties which differed completely from those of created substance. It followed for Priestley that no proof of the materiality of man could be extended by analogy to prove the materiality of God.

However Priestley did not accept God's immateriality,at least as his contemporaries defined immateriality. If they meant by immaterial

> ...a substance that has properties and powers essentially different from those of created matter, it is plain that I have no objection to the term, and in this sense I do believe it is, in fact, used by the generality of mankind.[97]

Although God possessed powers and properties different from those of men, to assume God to have no property in common with matter, nor any possible relation to space posed, he thought, an insurmountable difficulty:

> ...the divine Being is necessarily cut off from all communication with, and all action or influence upon, his own creation.[98]

Priestley discussed several considerations which, he believed, made the assumption of God's materiality as unobjectionable as immateriality.[99] Firstly, the materialist position removed the difficulty involved in supposing an immaterial Being to act upon a material creation. This argument assumed that the supposition of a single, though differentiated substance common to the Creator and his creation was a simpler and hence more philosophical argument, attributing but one substance to the phenomena (God and the universe). Because of Priestley's sceptioism concerning God's nature, his supposition of God's materiality was only hypothetical; and his clear distinction between the intelligent Creator and his creation made his system clearly theistic, despite its monism.

Secondly, to attribute self-motion to a material Deity posed no more of a mystery than to attribute the same to an immaterial Deity. In the Institutes, volume i, Priestley had maintained that

no created substance could originate motion in itself; and in Hartley's Theory of the Mind he had implied that mind could not do so, whether one supposed it to be material or immaterial because all mental effects have antecedent causes. In the Disquisitions he quoted Locke's remark:

> 'it is as hard to conceive self motion in a created immaterial, as in a created material being, consider it how we will,'[100]

and added that the difficulty remained when one removed self-motion to an uncreated Being. Because things existed, and had causes, there had to be an original cause, but concerning the nature of this cause,

> We are absolutely confounded, bewildered, and lost, when we attempt to speculate concerning it....[101]

Thirdly, Priestley claimed that the theory of matter put forward by Boscovich and Michell

> ...is much more consonant to the idea which the sacred writers give us of the omnipresence of the divine Being, and of his filling all in all, than that of a being who bears no relation to space, and therefore cannot properly be said to exist any where;which is the doctrine of the rigid immaterialists.[102]

Priestley regarded his own conception of the divine essence as the same with those

> ...who maintain the proper omnipresence, or ubiquity of the Divine Being, which necessarily implies a real extension; and that he has a power of acting upon matter.[103]

Priestley thought that anyone who believed that spirit possessed extension, and that God was ubiquitous, must accept the mutual penetrability of substance.[104] He did not object to those who said that his system denied the existence of matter, explaining all by spirit,

> ...provided they make as great a difference in spirits, as they have hitherto made in substances.[105]

God, as a substance, was ubiquitous, omnipotent, and capable of penetrating all other substances; but he did not constitute those substances, nor did he directly activate them, they being the

product of created powers. God was as different from other substances as creator and creation could be, and this Priestley believed to hold true whether the universe consisted of "substances" or "spirits".

Though the nature of God was incomprehensible, Priestley thought that if any one should,

> ...on account of the very few circumstances in which the Divine nature resembles other natures, think proper to apply the term material to both,...[106]

his theory of matter would render this

> ...a very different kind of materialism from that grosser sort, which, however, has been maintained by many pious christians, and was certainly the real belief of most of the early Fathers.[107]

Priestley emphasized the innocuous nature of the belief in God's materiality when he pointed out that most people regarded God as a corporeal Being;[108] and the scriptural representation of him as living in heaven, though not, to Priestley's mind, philosophically just, was nonetheless a completely innocent belief,[109] and indeed implied a possible scriptural support for God's material nature.

The belief in a material God did not seem atheistic to Priestley, and he stressed that it was a denial of the existence of an intelligent creator of the universe, rather than the denial of his immateriality, that constituted true atheism.[110] Priestley noted the silence of the Scriptures on God's immateriality, and found in this an indication of the unimportance of this doctrine; and, indeed, he noted something quite different:

> ...he is so far from being said to be what we now call immaterial, that every description of him, even in the New Testament, gives us an idea of something <u>filling</u>, and <u>penetrating all things</u>, and therefore of no form, or known mode of existence.[111]

Matter's supposed inertness had made it an unlikely support for the power of thought, Priestley claimed, for it had in the past

rendered untenable the materiality of the human or Divine mind. In Priestley's theory, matter could support thought, and the concomitant objection no longer held. Thus, although one could know nothing of the Divine nature which supported the properties of "supreme intelligence, omnipotence, unbounded goodness, and universal providence", it seemed to Priestley to be of no significance whether God's nature was termed immaterial or material,

> ...because it is not the substance, of which we have no idea at all, but the properties that are the object of our contemplation and regard.[112]

Using once again the principle of the compatibility of the properties of substance, Priestley said that man agreed on the divine attributes as revealed in the divine works,

> ...and provided that every person is fully satisfied that his own ideas of the Divine essence are consistent with the known attributes of divinity, they must necessarily be equally safe, and equally innocent.[113]

Thus, concerning the extension of his materialist system to the nature of God Priestley was as unwilling to admit the certainty of his hypothesis as he was to do so for any other substance. Michell's rules suggested to him that God's works and attributes as described in scriptural revelation permitted the possibility that God might conceivably be material or corporeal. Such an hypothesis seemed to Priestley no more mysterious than the supposition of an immaterial Being as the originator of motion, and he found the former hypothesis consonant with those Biblical descriptions of God which implied corporeality, and with those more "philosophically just" Biblical descriptions which implied God's proper ubiquity and constant governance.

Priestley's defence of the materiality of the mind as material substance, of man as material substance, and of Christ as man, culminated in the hypothesis of the corporeal nature of God. In

the Disquisitions Priestley took Michell's theory of substance to its furthest extent. He placed the work explicitly in the Newtonian tradition by his emphasis on Newton's rules of philosophizing, thus indicating his recognition of the value of Newton's simple but powerful epistemology. Newton's rule of the fewest possible causes provided a useful rationalization for Priestley's daring metaphysical speculations, and an appearance of respectability which he perhaps felt the work very much required, while also providing a useful supplement to Michell's monism, epistemology and theory of matter.

Nonetheless it seems to me that Michell's theory of powers, his analysis of our understanding of matter and its properties, and particularly his transformation of Baxter's immaterialism into a dynamic and monistic system,provided the basic ideas for Priestley's "immaterialist" materialist system, and suggested to him the possibility that a materialist position could be defensible.

CHAPTER SIX

RATIONALISM AND THE POWERS AND PROPERTIES OF SUBSTANCE IN MICHELL AND PRIESTLEY'S THEORIES OF MATTER

(1)

In this section I will discuss the "rationalism" of certain of the assumptions underlying Michell and Priestley's scientific writings, and its relation to their views on the nature of matter. In particular I will look at the role of mathematical reasoning and the debt to Newtonian thought apparent in Michell's work; the role of "necessity" in Priestley's thought; the nature of "mediation" in the work of both men; and the emphasis on the

interconneotness and rational organization of phenomena and on the uniformity of nature's laws whioh was a hallmark of the belief both men had in a universe governed by rational laws disoernible to men.

Miohell's soientifio work reveals an enormous debt to the mathematioal and rationalist elements in Newton's philosophy, so that even in his rejection of the "hard""massy" partioles proposed by Newton, his methodology, though not his oonolusion, was muoh influenoed by Newton. Indeed the Newtonian philosophy provided much of the method whereby Miohell oonstructed a theory of matter from what had been essentially a rational philosophioal speoulation developed from Baxter's metaphysios.

Miohell used the Newtonian concepts of foroes decreasing over distance aocording to a speoifio ratio, and the related ooncept of forces radiating from a point-source. He used the former in both algebraio and arithmetical forms to quantify a number of phenomena whioh he believed to be explicable in terms of the latter ooncept.

His positing in the Treatise of an inverse square law of magnetic force radiating outwards from poles whioh, he said, oould be considered as point-souroes, is the best known but not the only instance of such an application, for he used forms or analogues of the two concepts mentioned above in other areas of soience and teohnology.

In his 1760 paper on earthquakes he oonceived of shook-waves radiating outwards from a central source; and his proposed method for determining the epioentre of a quake assumed a point-source for purposes of caloulations, though he recognized that the rate of transmission of the waves could vary as they passed through different media, and hence that their force and velocity would

vary at different places which the outwardly radiating waves reached.[1] Thus the rate of propagation of shock-waves was not invariable, which differed from the inverse square law of magnetism, the latter, Michell had stressed, not being affected by the interposition of solid bodies, so that their field of activity could be considered as uniform.

In the theory of "molecular magnets" (discussed in chapter two) which he described to Boscovich in the same year as the publication of the paper on quakes, Michell posited a combination of single and bi-focal point-sources and mathematically determinable resultant strengths of force. Each magnetic particle possessed two point-sources, one of attraction and one of repulsion, and the strengths decreased over distance.

In one of the drawings for his 1765 paper on the use of Hadley's quadrant for surveying Michell showed arcs passing through each of two points (representing landmarks) and radiating outwards from a line intersecting the points.[2] The quadrant would be used in conjunction with charts showing how a ship's location could be calculated once the angle subtended by the two landmarks had been determined by use of the quadrant. There is a striking analogy between this drawing with its two point-foci and the concept of two points radiating respectively attractive and repulsive powers in Michell's theory of "molecular magnets".

The arithmetical and geometrical concepts of ratio, central to Newton's work, played an important part in Michell's theory of magnetism and his theory of molecular magnets. The notion of 'ratio' assumes the existence of 'harmony' or 'proportion' in the universe and its governance according to some law or plan, the mathematical expression of which is found in the concept of 'ratio' or 'proportion'. Rationalism is in part the belief in man's ability

to perceive this harmony through use of his reason, whereby he apprehends the laws ordained by God's reason for the ordering of the Universe. Though neither Michell nor Priestley explicitly identified the powers of nature as laws of nature, they clearly saw the powers of nature as means whereby God ordered the universe; and the role of mathematical ratios in their description of the powers of nature suggests the "rationalism" of their assumptions in its literal sense.

In Michell's work on light, and particularly in his calculation of the momentum of light at emission from the sun (described in chapter three) one saw the deductive nature of his thought, and his use of geometrical reasoning and of Newton's propositions in particular. As I mentioned there, Michell's reasoning on the nature of light was not readily susceptible to empirical verification, though the experiment on the momentum of light was perhaps intended as such; and he appears to have assumed (perhaps from his reasoning on penetrability) that light particles must indeed possess momentum to be able to pass through transparent substances.

Michell's recognition of the enormous value of the Newtonian philosophy can also be seen in more mundane matters, as, for example, in the care he took over the texts from Newton's Opticks and Principia which Priestley used in the History of Optics. Michell checked and revised some parts of Motte's translation of the Principia for Priestley; and Priestley himself was anxious to convey the spirit of the Newtonian text, emphasizing in his justification of certain minor abridgments and updatings of Newton that he was concerned to make the texts as accessible and trustworthy as possible.[3]

In summary, the mathematical and deductive nature of much of Michell's scientific thought was particularly exemplified in

his debt to Newton.[4] It is ironic that the theory of matter which he developed owed so much to Newton, and yet denied one of Newton's basic postulates, the impenetrability of particles. However, Michell had arrived at the theory of penetrability through philosophical speculation; and starting from this basis, even though using Newtonian methods, he developed a dynamic theory of matter which, in certain fundamental respects, differed radically from Newton's corpuscular philosophy.

Priestley's use of the concept of necessity reflects, I believe, the rationalism which underlay his thought. Priestley borrowed the concept from Hartley and applied it to describe the dynamic relationships subsisting between matter and powers, powers and powers, and powers and properties. The concept is crucial to an understanding of Priestley (and Michell's) theory of matter and its metaphysical assumptions; and indeed Priestley's usage indicates a major distinction between the necessarian and monistic pantheism of Spinoza, and the necessarian and monistic theism which he himself espoused.[5]

The term "necessary" implies an always occurring relationship that is ordered according to some fixed and discernible law or principle. It is the opposite of "arbitrary", which implies a relationship governed by no fixed law or principle, and determined by the incomprehensible activity of some body or of some conscious will. Priestley's attribution of necessity to relationships in theory of matter, in psychology, and in metaphysics can be seen, I think, as an indication of his belief in the governance of the universe according to fixed laws and rational (and hence discernible) principles; the one major exception to this premiss being his acceptance of the power of a rational, omniscient and omnipotent creator to intervene in the operations of these laws in order to

reveal certain truths to man.[6] This exception represents a major difference between Priestley's and Spinoza's system; and yet the emphasis on necessity also highlights Priestley's differences with many (though by no means all) of the divines of the eighteenth century who attributed freedom of the will to both man and God.

Priestley had stated in volume one of the Institutes that no created substance had the power of self-motion;[7] and that principle, which he applied in his materialist psychology and in his theory of matter, defined in part his conception of all relationships existing in the universe: all events (including human thought) and all substances (including mind) were caused by other events and substances; and no event or substance could be regarded as independent of other events and substances.

In his Examination of Dr. Reid's Inquiry, Priestley claimed that Reid had

> ...introduced almost universal scepticism and confusion; denying all the connections which had before been supposed to subsist between the several phaenomena, powers, and operations of the mind, and substituting such a number of independent, arbitrary, instinctive principles, that the very enumeration of them is really tiresome.[8]

In that brief critique Priestley virtually summarized his own metaphysics and epistemology: phenomena were interconnected (not independent), necessary and lawful (not arbitrary), and being the products of God's reason, were discernible by man's rational faculties (instinct having no part in Priestley's rationalist system). The result of the denial of these connections, Priestley thought, was scepticism (a virtual confession of ignorance concerning the relations of phenomena); and a concomitant disbelief in their ordering by a rational plan and mind. This argument suggests to me that Priestley saw the latter as leading to either a disbelief in the existence of controlling mind; or alternatively, to the

acceptance of a completely arbitrary and incomprehensible God, both of which contradicted his own rationalism and his belief in the existence of a benevolent and just God.

Priestley's emphasis on the "necessary" nature of relationships perhaps explains his readiness to accept Michell's description of the connection between substance and its powers and properties. In a letter of 1773 Priestley observed:

> Mr. Michell supposes that wherever the properties or powers of any substance are, there is the substance itself, something that we call substance being necessary to the support of any properties; but what any substance is, devoid of all properties, we cannot, from the nature of the thing, have any idea whatever; since all the notices that we receive of any substance are communicated to us by means of its properties, and such as bear some relation to our senses, which are the inlets to all our knowledge.[9]

Michell's neo-Lockean description of substance as a support of properties, and the latter as powers whereby we apprehend substance,[10] posited an epistemology in which the powers of matter were the cause of man's perception of properties, and thus the cause of man's knowledge. Such a theory was acceptable to Priestley for he regarded ideas as the result of the association of sense impressions mechanically communicated to the brain.

Michell's system denied the independence and self-motion of both matter and mind: the powers of matter acted upon the powers of mind; and one did not need to consider either substance, matter or material mind as existing, except in so far as one supposed them as the support of the properties. Michell's system in effect abolished matter as an unnecessary supposition mediating between powers and the resultant properties: Lockean scepticism became in his system the virtual abolition of any "essence" or "substance", and its replacement by a direct and necessary connection between powers and properties.

The question of mediation is a vexing one for Priestley's

science, metaphysics and theology;[11] and Michell's positing of immediate contact (i.e. contact without mediation) throws light on this issue and on the nature of Priestley's view of necessary relationships as being causal, dynamic and immediate.

Michell's transformation of matter into powers permitted immediate contact between powers, and between bodies which were constituted of powers. By so doing Michell rejected absolute impenetrability and its usual concomitant, the assumption of an infinite force of repulsion possessed by particles, an assumption made explicit in Boscovich's theory.

Priestley claimed in the Disquisitions that the assumption of the mutual penetrability of matter was a conclusion in harmony with the Biblical statements which conceived of God as being omnipresent, of being "all in all".[12] Elsewhere he rejected atomism as an atheistic hypothesis;[13] and although he never said as much, it seems to me that the supposition of particles possessing only finite powers of repulsion was perhaps a means for him to have a point-atomic theory without the danger of introducing what he regarded as an atheistical hypothesis into his theory of matter.

In a letter of 1777, Boscovich accused Priestley of distorting his (Boscovich's) theory of matter and converting it to atheistical purposes.[14] Boscovich, as we have seen, had posited an infinite repulsive power surrounding his point-atoms, and it is ironic to see the two great physicists differing on a fundamental postulate of their physical theory and yet being unable to see clearly what the other was saying, nor why he said it; and even more ironic when each was advancing a theory with theistic assumptions in mind.

Boscovich's theory posited the basic role of point-atoms as the source of inter-particulate forces, which was the opposite of Michell and Priestley's supposition of powers as the cause of

matter (which was merely a supposed support of the properties by which powers rendered "matter" perceptible). The differences between Boscovich's, and Michell and Priestley's views on immediate contact and on the magnitude of repulsive forces (despite Priestley's incorrect attribution of penetrability to Boscovich's theory) reflect this fundamental disagreement; and Priestley's identification of Boscovich's theory with Michell's does not hide this basic difference.

Newton had accepted absolute impenetrability; while Leibniz had rejected the supposition of any infinite force.[15] Boscovich gave absolute impenetrability of each as one of the basic postulates of his physical theory. Michell and Priestley accepted the mutual penetrability of matter which Newton and Boscovich denied, and on this question they seem to have been closer to Leibniz who rejected the possibility of any infinite force. Because Michell did not think that there was an insuperable repulsive power surrounding any "particle" of matter, it followed that particles were capable of immediate contact, and nothing could then prevent mutual compenetration of the particles. Immediate contact was a dynamic process which required the overcoming of powers of repulsion, and resulted in the alteration of the previous balance of powers and could produce, whether in magnets, particles of light, or particles of matter, a change in polarity, (the dynamic transformation of a power of repulsion into one of attraction, or vice versa). Thus powers could contact and affect each other, and no mediation was necessary for the contact and the effect to occur.

A common (or perhaps one might say, "mediating") property was necessary for the contact to become possible, for as Michell implied and Priestley stated, some common property was necessary for one substance to affect any other; but the common property

did not itself accomplish the interaction or cause the effect, for immediate contact permitted the bodies or powers to affect each other directly. The common property was purely catalytic, for it did not take part as a causal agent in the process when immediate contact had been achieved.

Unlike the aetherial medium which Newton had posited at times as the vehicle or medium whereby light was transmitted, the common property which Priestley invoked as a *sine qua non* was not itself a substance, but only a property of substance, indeed a property of the very substances which were affecting each other, so that any body possessed the very mediating property which was required for it to affect other bodies.

There was, I believe, an underlying assumption of a hierarchy of powers in Priestley's scientific and metaphysical writings from the mid-1770's on, with various classes of powers distinguishing the different forms whereby substance was made manifest to the human observer. Priestley's "great chain" of powers had as its basis and apex the Divine powers which created and kept active all the finite powers, from the physical powers to the highest created powers of perception and thought.

Powers were in effect the interactions of different forms of substance and Priestley had argued that the existence of some common property was necessary for this interaction to occur. The common property permitted interaction, with the power being the mediating activity which constituted the relationship.

The ideas on substance and powers which Michell had imparted to Priestley during the preparation of the *History of Optics* were the basis, I believe, of Priestley's hierarchical theory of powers. The possibility of immediate contact and of mutual penetrability of bodies, and the assumption that bodies were constituted solely

of powers, permitted the extension of Michell's theory of substance to all types of substance; and Michell's epistemology with its definitional prescription of properties provided the means whereby the relation between powers, properties and substance could be defined with regard to any of the powers by which the substance was made manifest to the human observer.

The simplest and most basic powers were the physical powers of attraction and repulsion which Priestley attributed to matter; while electricity, magnetism and gravitation were more complex physical powers.

His application of a dynamic theory of matter to the nature of mind led to his positing additional powers of matter, namely the powers of sensation, perception, association of ideas, and thought. These, he said in Hartley's Theory, were compatible with the powers of attraction and repulsion; but his very mention of their compatibility implied a distinction between mental powers and the physical powers to which they were related.

Just as the relationship between matter and its physical powers was a dynamic one, with the powers by their activity constituting matter, so the relationship between matter and mental powers was dynamic. The brain in Priestley's materialist psychology consisted solely of matter, but possessed an organized form which resulted in the dynamic powers of the mind. The power of association in conjunction with the vibrations of particles in the brain and nervous system (the vibrations themselves a result of the repulsive powers of matter) resulted in the power of thought, which was, however, according to Priestley, distinct from the physical powers, and compatible with them, but not a mere product of them, not identical with them. This was so despite the fact that they shared in common an underlying substance which was identical in form,

and which provided the "compatibility" (in the form of common properties) which Priestley maintained was essential for the interaction of any two forms of substance.

With his synthesis of matter and spirit, one may speculate that the sharing of a common property was for him a necessary condition for powers to interact as it had been for substances to interact. In the History of Optics he had spoken of the counterbalancing and overruling of attraction and repulsion by each other; and the possibility of two classes of powers such as physical and mental powers affecting each other seems to me a distinct possibility in his system, and the facts of "compatibility" and of an underlying common substance render a dynamic relationship between these two classes of powers likely. This would be in addition to the dynamic relationship already existing between matter and physical powers, between the physical powers themselves, and between matter and thought.

Priestley's research in pneumatic chemistry and in the physiology of respiration occupied much of his time from the early 1770's on, and added a new dimension to his studies in natural philosophy, providing him with a further "inlet" to the powers of nature. In his writings on these subjects I believe one can see Priestley filling in the gap which existed between the physical powers and the mental powers.

He used the powers of "animalization" and "vegetation"[16] to describe the powers which produced animal and vegetable substance; and on occasion spoke of the chemical powers as responsible for the various chemical processes. Thus Priestley's work in these areas suggests a hierarchy of powers: simple physical, more complex physical, chemical, biological (first vegetation, then the more complex animalization, then sensation), leading finally to the

mental powers of perception, association of ideas, and thought. This was a hierarchy of powers rather than of substances, with powers producing perceptible properties whereby the observer distinguished the various manifestations of substance.

The idea of the uniformity of nature and of nature's laws is related in Priestley's work to the idea of necessity in that the lawful quality of necessary relationships is assumed to hold everywhere and at all times. These laws did not change from place to place and time to time by the action of an arbitrary will; and similarly uniformity was regarded as a result of the rational activity of an omnipotent Creator.

Priestley spoke of the "uniformity" of nature's laws;[17] and one may speculate that his assumption of the dynamic powers of matter which he thought to operate constantly and in all types of substance, reflected a belief that the physical and chemical properties of substance were the result of the uniform activity of these powers. Michell's "doctrine of attractions and repulsions" which Priestley accepted in the History of Optics could perhaps have formed, if Priestley had so desired, a physical basis on which to construct a chemical theory; but there does not appear to me to be any direct connection between his theory of the penetrability of matter on one hand, and his chemical experimentation, his attempts at constructing a chemical theory, and his defense of phlogiston on the other.[18]

John Michell's defense in his 1767 paper on the parallax of the organization of the heavens according to some as yet unknown law of the Creator assumed order if not uniformity in the heavens.[19] He rejected random arrangement of the stars, thus presenting a defense of the ordering of the stars according to some rational plan, with the implicit assumption, it seems to me, that the rational

faculties of man (presumably including mathematical analysis) in conjunction with astronomical observation would be able to discern such a plan.

Michell attempted to discern some "design" or "general law" by the use of analogy and probability arguments.[20] Analogy is a type of reasoning which assumes some common property shared by different types or classes of phenomena (an interesting parallel with Priestley's insistence on a common property as a necessary condition for interaction between substances to occur); and arguments from probability assume that law or connection can be discerned in a group of apparently unrelated phenomena, similar to Priestley's belief (stated in his critique of Reid) in the connectedness of phenomena.[21]

In summary, the concept of necessity used by Priestley, and the concept of uniformity in both his work and Michell's, indicate the existence of rationalist assumptions about the organization of matter; and the mathematical and deductive arguments used by Michell in his elaboration of that theory of matter seem to be further confirmation of the existence in their work of underlying assumptions about the rational laws governing the universe and the substance of which it is composed.

(11)

The concept of "theory" can perhaps provide a key to an understanding of Michell's dynamic and monistic epistemology and theory of matter. The hypothetical arguments with which he advanced his ideas concerning the possibility of penetrability as a viable theory of matter[22] suggest to me an awareness of the difficulty with which man combines the findings of his observation with the reasonings of his mind. His ideas on matter were unorthodox, and he recognized the need for linking in a satisfactory manner the concept of penetrability (developed through metaphysical speculation) with the findings of natural philosophy.

Michell's research on different types of substance perhaps gave him a practical concern for the way in which men used the powers of nature; and his observation, often for practical purposes, of the properties of substance perhaps gave him the requisite knowledge to generalize concerning the relationship between substances, powers and properties in a manner and with a result similar to the relationship between reason and observation implicit in his scientific work.

It appeared in chapter three, section four, that Michell probably developed his theory of the penetrability of matter before he did the experiments, calculations and reasonings on Light and matter described in the History of Optics. The source of this theory was his rational analysis and transformation of Baxter's dualist system; he saw the confirmation of this theory in the experiment on the momentum of light, though he carried out the explication of his ideas on the emission, momentum, refraction and reflection of light, as we have seen, principally by the use of mathematical and deductive reasoning.

Michell outlined his view of the relation between theory and experiment in a letter to his friend Benjamin Wilson in 1754:

> ...I oan neither sit down to make experiments, that have been made before (& with whioh I am already well aoquainted) unless I thought, that they were not altogether satisfaotory, & I could make them with more oertainty & acouraoy; nor can I go to make experiments, to see what will be the effect, unless I have some System or particular end in view, whioh I want to try by the test of Experiment or in which I see some oonnexion with some known Faots.[23]

The experiment on momentum appears to have fulfilled all of these requirements: Michell thought he oould improve upon the results previously obtained by Homberg and Mairan;[24] he was conoerned, at least according to Priestley, to test 'some system' or view, namely the oorpusoular theory of light; and he perhaps hoped the experiment would provide empirical verification for his theory of the penetrability of matter, whioh he had developed through philosophical analysis, but which he oould perhaps verify empirically if he could show that particles of light possessed momentum.

His statement to Wilson suggested he saw the establishment of the existenoe and nature of the relationship between a fact or theory and other faots and theories as being a prime motivation for scientific experiment. He was interested in the magnetio and other physical properties of steel and iron by the time of his 1750 publication of the Treatise of Artificial Magnets, and discussed both applications and the theory of the subject. His theory of molecular magnets was in part an explanation of the process of magnetization. Michell's knowledge of metals was of assistance to Priestley's ohemical studies in the early 1770's; and he supplied Priestley with a number of the metals and semi-metals with whioh he carried out some of his experiments.[25] The strength of metals was of practioal concern to him in the early 1780's while attempting to improve his method of building telescopes;[26] and in the same

period he wrote to Savile a letter concerning a proposed new type of coinage.[27]

Michell was also interested in the physical properties and practical uses of other substances, most notably various types of rocks; and here his interest in geology and stratigraphy, in engineering and in the physical properties of materials merged on occasion as early as 1759. In that year, by which time his paper on earthquakes with its discussion of stratigraphy and the thickness and density of various media and strata was in circulation, a letter to Savile included a discussion of the various types of rocks in England and mention of the fact that he had built a scale model to test the physical properties of a suitable type of stone and the feasibility of the design.[29] As late as 1783 Michell was planning a series of experiments on the strength and compressibility of different types of stone and wood, and was interested in doing the same for metals.[30]

Michell's apparent reluctance to publish more extensively was perhaps a result of an unwillingness to publish facts or experiments unless they could be related to a theory. This emphasis on the necessity of theory is apparent in his scientific and technological writings.

The brief theoretical section on magnetic power in the Treatise of Artificial Magnets was presented as a prelude to a possible work on the theory of magnetism. In the Treatise we saw his ability to marshall experimentation in defense of propositions concerning magnetic power, and his reluctance to present as proved a proposition (namely the inverse square law) because of his uncertainty that he had obtained adequate demonstration of it.[31] As a technological work, too, the Treatise was not a mere recitation of facts, but presented methods of making artificial magnets in a clearly compre-

hensible manner.

In a letter which he wrote more than thirty years later, he emphasized in a discussion of his experiments with improving the quality of telescope mirrors that his chief concern was not the actual production for himself of a better telescope, but rather the (much more demanding) task of determining how exactly this could be done in order that he could present to other instrument-makers a description of a dependable method of so doing.[32] In his 1760 paper on earthquakes Michell sought to establish a 'vulcanic' theory to explain the cause of earthquakes, and he also advanced his method for determining the epicentres of quakes; and his 1765 and 1767 papers on surveying and the determination of longitude presented applications of mathematical instruments as means of dealing with specific problems.

Michell's technological work shows his concern with purposefulness in a more practical sense. His interest in surveying, bridge-building and bridge-design, and in the building of telescopes and the improvement of the chronometer were practical and applied manifestations of his virtuosity as a mathematician and scientist; and were the sort of interests which he shared in common with (amongst others) his friends Savile, Smeaton, and Priestley.[33] Priestley perhaps articulated the assumptions underlying this common desire to harness the powers of nature when he observed that the application of knowledge for the improvement of man's condition was the means whereby men could realize the happiness and fulfillment of their fellows which Priestley assumed to be the plan of a benevolent God.[34] That human beings could understand and hence improve the condition of themselves and others was one of the basic assumptions of the liberal rationalism which Priestley espoused, and to which Michell and Savile lent their support.

Michell's interest in the properties of substances was a common theme in his technological interests, his physical researches, and in his metaphysical and epistemological speculations. The "inlet" into the nature of matter which he found was not, as Priestley had suggested in the History of Electricity, through a discovery in natural philosophy, but rather a metaphysical speculation on the penetrability of matter. The conclusion which he drew of the identity of substance with the powers which produced it and the properties whereby it made itself manifest, was one whioh could potentially impose a unity on the varied researches on substance which he had carried out. As such it was, I believe, an expression of his rationalist faith in the possibility of understanding the harmony of a world, the knowledge of which was to be a means whereby men could fulfill the expectations of a benevolent God.

CONCLUSION

Michell developed a theory of molecular magnets based on his earlier research in magnetic theory. The concept of "points" of attraction and repulsion was probably a refinement of his original idea that the point-source poles of an artificial magnet could be brought together as close as one wished. The resulting theory employed neither vortices nor fluids, as Boscovich noted, and was an interesting application of the concept of point-sources with forces radiating outwards which Newton had used, and which Michell himself had applied in his theory of earthquakes, his theory of magnetism, and which he later used in his general theory of matter.

Michell's use of point-sources in his theory of molecular magnets means that one could speak of his theory as point-atomic, if one considered a pair of points as constituting a magnetic molecule or molecular magnet. However, Michell transformed this "point-atomic" theory into a theory of penetrable matter in which the mutual penetration of matter and of points was possible, thereby denying one of the basic tenets of classical and of eighteenth-century atomism, namely the absolute hardness or impenetrability of atoms. This was perhaps a very important consideration for Priestley in his adoption and application of Michell's theory of matter, given the former's opinion that atomism was atheistical.

Michell's supposition of the mutual compenetration of matter, which was an extension of his idea that immediate contact was possible because repulsive powers were finite, rendered his theory the converse of Boscovich's in certain aspects, for the latter supposed as one of his basic postulates the impossibility of immediate contact and hence of "true" compenetration. Michell's monistic synthesis of matter and powers was a very different hypothesis from Boscovich's supposition that point-atoms and powers were logically separable and physically separate entities.

Michell's theory of penetrability implied a denial of Newton's concept of impenetrable particles; and even though Michell used Newtonian propositions, Newton's concept of point-sources, his idea of attractive and repulsive forces, and a mathematical and deductive reasoning based principally on Newton's, his theory denied an essential tenet of Newton's corpusoular theory, impenetrability.

Priestley placed Michell's dynamic theory of matter in the Newtonian tradition by arguing that Newton's concept of the void and the resulting "universe in a nut-shell" hypothesis led almost inevitably to the supposition that solidity had no role to play in

nature. Yet Priestley's argument obscured the very real difference between supposing impenetrable particles of howsoever small dimensions, and the supposition of penetrable particles which consisted only of powers. Priestley's confusing of the two separate questions of penetrability and of the void was perhaps necessary if he were to place Michell's theory of penetrability in the Newtonian tradition; but there is no indication that Michell confused the two issues.

Priestley's failure to distinguish between these two questions, and his apparent inability to note the major differences between Michell's and Boscovich's theories of matter did not lessen his enthusiasm for Michell's theory of matter, nor did it discourage him from attempting to extend it from the optical speculations in which he first saw Michell apply it, to psychological and metaphysical problems. Priestley's "immaterialist" materialism, based on Michell's transformation of Baxter, and stated most clearly and forcefully in his central work, the Disquisitions Relating to Matter and Spirit, was the most innovative and exciting of his metaphysical ideas, and certainly the most controversial. His concept of powers and the implied hierarchy of powers which was first hinted at in Hartley's Theory, utilized Michell's theory of the relationship between substance and its properties, with its implicit abolition of substance as an intermediary between powers and the properties which they generated and underlay.

Thus, in conclusion, Michell had speculated rationally on the nature of matter, and had been led to posit the penetrability of matter. He perhaps found confirmation of this hypothesis in his theory of molecular magnets with the point-sources brought as close together as possible; and he certainly believed he found confirmation of it in the momentum of light which he thought responsible for its

ability to penetrate matter. He developed a dynamic theory to explain the emission, momentum, refraction and reflection of light by the activity of surface powers of attraction and repulsion.

His researches into the properties of substances, including his technologically-inspired investigations into the physical, and particularly building properties of substances, perhaps posed for him the problem of describing the relationship between substances and their observed and usable properties. He resolved this issue in an epistemology which owed much to Newton and Locke, and which described appearances as the product of the powers which he supposed to underlie those appearances. Man's perception of the world then became, as Priestley argued in the Examination of Reid, the result of the universe impressing itself upon the observer's senses; and Michell's dynamic theory of matter provided the framework in which Priestley was able to explicate an epistemology and a metaphysic in which the highest powers, the active mental powers of man the observer, could be united in a single system with the physical, chemical and biological powers of the universe to which they were related. This system, based on dynamic, lawful and necessary relationships, was Priestley's expression of the rationalist and theistic ideas which inspired in him and Michell a belief in a divinely ordered harmony of the universe.

NOTES AND REFERENCES

Introduction

[1]Institution of Civil Engineers, Smeaton's Machine Letters, vol. iv, p. 162, Smeaton to Michell, 23 November 1785.

[2]L. L. Whyte, "Boscovich's Atomism," in Whyte, ed., Roger Joseph Boscovich, (London, 1961), p. 118. Whyte said that Michell, Boscovich and Kant favoured physical point-centres.

[3]C. L. Hardin, "The Scientific Work of the Reverend John Michell," Annals of Science, xxii (1966), 27-47; R. McCormmach, "John Michell and Henry Cavendish: Weighing the Stars," British Journal for the History of Science, iv (1968), 126-155.

Chapter One

[1]A. Geikie, Memoir of John Michell, (Cambridge, 1918); C.L. Hardin, "The Scientific Work of the Reverend John Michell," Annals of Science, xxii (1966), 27-47.

[2]Nottinghamshire County Record Office, Bishop's Transcripts of Parish Register, 1603-1808 (microfilm), (Eakring parish).

[3]This paragraph is based on Geikie, Memoir, pp.4-5.

[4]"A Recommendation of Hadley's Quadrant for surveying, especially the surveying of Harbours, together with a particular Application of it in some Cases of Pilotage," Philosophical Transactions, lv (1765), 70-78; also printed separately in London, 1765.

[5]Michell spoke of Mason's co-operation at Cambridge in making astronomical observations of the comet of January 1760 in his brief account of the Comet, Phil. Trans., li (1760), 466-467.

[6]B. Franklin, Memoirs of Benjamin Franklin, 2 vols., (New York, 1845), vii, pp.207-208. Franklin discussed Michell's paper on strata and earthquakes which he was forwarding to Dr. John Pringle; letter to Pringle, 6 January 1758.

[7]Royal Society, London, Annals of the Royal Society Dining Club (manuscript volumes), vol. i, cites a "Mr. Mitchel" as a visitor on 7 July 1748. Gowin Knight was one of the members present.

[8]In a note added to a letter of Michell's in the Monthly Review, lxxii (1785), 479, Smeaton spoke of his observation of the experiments in 1749 and 1750, and defended Michell against Canton's claims.

[9]R.E. Schofield, Lunar Society of Birmingham, (Oxford, 1963), p.24. The letter, quoted by Schofield, was dated 5 July; and Michell mentioned Boulton's "great civility" to him in Birmingham the

previous year.

[10]British Museum Additional Manuscripts no. 30094, folio 86, Michell to Wilson, dated at Cambridge, 22 December 1754.

[11]Royal Society, London, certificate recommending Michell for fellowship in the society, dated 6 March 1760, and signed by Sir George Savile, Gowin Knight and John Hadley among others. Michell was elected on 12 June.

[12]"Proposal of a Method for measuring Degrees of Longitude upon parallels of the Equator," Phil. Trans., lvi (1766), 119-125; also printed separately in London, 1767.

[13]Michell missed the meeting of 12 September 1765 on account of his first wife's illness (B.M.Add.MSS. 39822, f. 35). This is one of the few references to his first wife, who died soon afterwards.

[14]Phil. Trans., lvii (1767), 234-264; also printed separately in London, 1768.

[15]Cavendish Collections, Chatsworth, Michell Correspondence, letter of Michell to Henry Cavendish, 2 July 1783.

[16]H. Cavendish, "Experiments to determine the Density of the Earth," Phil. Trans., lxxxviii (1798), 469.

[17]Royal Astronomical Society, London, Michell to Herschel, 12 April 1781; Cavendish Collections, Michell to Cavendish, 26 May 1783.

[18]American Philosophical Society Library, Philadelphia, Penn., Letter from Michell to Sir Charles Blagden, dated Thornhill, 27 July 1785.

[19]Gilbert Michell left these hothouses in the rectory grounds to his brother, John, in his will. (Public Record Office, Prob. 11/1229, Section 97).

[20]Royal Ast. Soc., Herschel MSS; W. 1/13, T. 10 & 11, (two letters from Turton to Herschel dated 1 and 10 July 1793).

[21]Notts. C.R.O., Savile of Rufford MSS. DDSR. 221/87; these include a number of letters dated between 1743 and 1753 from Rev. Gilbert Michell, John Michell's father, to Gertrude Savile, sister of the seventh baronet and aunt of the eight baronet. These letters are helpful on John Michell's early life and career. The Savile of Rufford Manuscripts and the Foljambe Manuscripts (also in the Notts. C.R.O.) contain in addition a number of letters from John Michell to the eighth baronet, and these will be referred to presently.

[22]Information from Gordon Elliott, University of Toronto.

[23]D. Hartley, A View of the Present Evidence For and Against Mrs. Stephen's Medicines..., (London, 1739), p.182.

[24]D.N.B. article, "David Hartley", 1891 ed., vol. xxv, p.67; N. Saunderson, The Elements of Algebra, in Ten Books, (Cambridge, 1740), list of subscribers at the beginning of the work.

[25]Notts. C.R.O., DDSR. 221/87, letter of 17 November 1746.

[26]Ibid., letter of 9 June 1749.

[27]Ibid., letter of 28 May 1748.

[28]Ibid., letter of 9 June 1749.

[29]DDSR. 219/3, letter from Michell to Savile, 30 July 1766.

[30]Berkshire C.R.O., Hartley Russell MSS., D/EHy 0.47, letter from Michell to Savile, 1 February 1759.

[31]"Recommendation of Hadley's Quadrant," 74-78.

[32]J.J. Sheahan, History of the Town and Port of Kingston-upon- Hull, 2nd ed., (Beverley 1866?), p.412. Savile "was one of the original shareholders of the Hull Dock Company when they were incorporated in 1774".

[33]M. Taylor, ed., Reports of the late John Smeaton, 2nd ed., 2 vols., (London, 1837), v.ii, p.117.

[34]Notts. C.R.O., Foljambe MSS. I/234, Smeaton to Savile, 21

January 1768.

[35]Foljambe MSS. I/249, Michell to Savile, 7 August 1772.

[36]Foljambe MSS. C/112, Michell to Savile, 23 January 1783.

[37]Hartley Russell MSS., D/Hy 0.48, two letters from Gilbert Michell to Savile, dated 13 and 22 April 1781.

[38]P.R.O., Prob. 11/1113, Section 101-102.

[39]DDSR. 221/93, Michell to Savile, 10 August 1782.

[40]B.M. Add. MSS. 30094, f.86, Michell to Benjamin Wilson, 22 December 1754.

[41]P.R.O. Prob. 11/1113, Sections 101-102.

[42]Royal Ast. Soc., Michell to William Watson, 21 January 1781.

[43]Royal Society, Canton Papers, vol. ii, f. 79.

[44]Priestley wrote his memoirs, dated at Birmingham in 1787; and compiled a further continuation to 1795 in Northumberland, Pennsylvania, where he settled after leaving England in 1794. The 1806 edition has been reprinted, with notes and introductory essays by J. Lindsay as Autobiography of Joseph Priestley, (Bath, 1970).

[45]See chapter five of this thesis.

[46]Autobiography, ed. Lindsay, p. 87.

[47]History of Electricity, p. viii (incorrectly numbered vii in the first edition). Unless otherwise stated, the works by Priestley referred to in these notes are the first editions.

[48]D. McKie, "Joseph Priestley and the Copley Medal," Ambix, ix (1961), 13-14.

[49]Priestley referred in his Memoirs, p. 96, to "The review of my 'History of Electricity', by Mr. Bewley, who was acquainted with Mr. Michell...." This review appeared in the Monthly Review, the same journal in which Bewley had reviewed Michell's Treatise of Artificial Magnets seventeen years earlier (B.C.Nangle, The Monthly Review. First Series. 1749-1789. Indexes of Contributors

and Articles, (Oxford, 1934), p. 158, article 2849). One may speculate that perhaps Bewley suggested to the two men that they meet, though a number of other mutual acquaintances, such as Franklin, Watson or Lindsey could also have done so. Michell perhaps heard of Priestley's History of Electricity directly from Franklin or Watson while the book was being written; and the attention it received at the Royal Society and in scientific circles in general would probably have brought the work and its author to Michell's attention.

[50]Priestley, History and Present State of Discoveries Relating to Vision, Light, and Colours, 2 vols., (London, 1772), i, p. vi.

[51]Memoirs of Dr. Joseph Priestley, (London, 1806), pp. 149, 456.

[52]Phil. Trans., lxii (1772), 147-264.

[53]Priestley, An Examination of Dr. Reid's Inquiry, (London, 1774).

Chapter Two

[1]A. Rivoire, Traité sur les Aimans Artificiels, (Paris, 1752).

[2]Treatise of Artificial Magnets, (Cambridge, 1750), pp. 26-27.

[3]Canton, A Method of Making Artificial Magnets Without the Use of Natural Ones, (London, 1751), pp. 6-10.

[4]Michell remarked in the Monthly Review, lxxii (1785), 480, that Canton's method seemed to be similar to his own, with possible additions from the method of du Hamel published in the Mémoires of the Royal Academy of Sciences of Paris in 1745. W. Snow Harris agreed with this suggestion in Rudimentary Magnetism, (London, 1872), p.101, observing that Canton combined the serial arrangement of Michell's method with the pieces of soft iron connecting the parallel lengths of du Hamel's.

[5]Monthly Review, lxxii (1785), 478-480, letter dated at Thornhill, 17 May 1785.

[6]A note appended to Michell's letter in the Monthly Review, is signed "J.S." and begins "Mr. Smeaton remembers;" Smeaton comments favourably on Michell's priority. He adds that Knight was very irritated by Canton's display of experiments to the Royal Society at a crucial stage in Knight's negotiation with the Navy Board over the purchase of his magnets, but that Knight remained a friend of Michell's "ever after".

[7]Royal Society, Canton Papers, vol. ii, p. 79.

[8]Ibid., vol. ii, p.114. Priestley to William Canton, 4 July 1785, said that amongst John Canton's paper was a note in Michell's handwriting saying that the bars referred to on page 10 of the Treatise (presumably the second edition, 1751, because the reference is to magnets Michell had seen since the publication of the first edition) were those of Canton.

[9]*Treatise*, p.1.

[10]*History of Electricity*, p.xiii.

[11]*Treatise*, pp.11-12.

[12]*Ibid.*, p.13.

[13]*Ibid.*, p.13.

[14]*Ibid.*, p.13.

[15]*Ibid.*, p.13.

[16]*Ibid.*, pp. 14-15.

[17]*Ibid.*, pp.16-17.

[18]*Ibid.*, pp.17-20.

[19]*Ibid.*, p.2.

[20]*Ibid.*, p.17.

[21]*Ibid.*, note to p.17 (continued on p.18). Proposition three reads: "...Each Pole attracts or repels exactly equally, at equal distances, in every direction." (p. 17).

[22]University of California, Berkeley, Rare Books Department, Boscovich Papers, letter to his brother Bartolomeo, 20 November 1760 (microfilm).

[23] *Treatise*, p. 17; "...this Attraction and Repulsion of Magnets is not at all hindered, or increased by the interposition of any Body whatsoever; though sometimes in *appearance* perhaps it may be increased by the interposition of such Bodies, as become Magnetical when in contact with, or upon their approach towards the Magnets, between which they are placed."

[24] See above in this chapter, quotation numbered 21.

[25]*Treatise*,pp.19-20; "...the Attraction and Repulsion of Magnets decrease, as the Squares of the distances from the respective Poles increase.

"This property, from some experiments I have made myself, and from those I have seen of others, seems very probable; but I do not

pretend to lay it down as certain, not having made experiments enough yet, to determine it with sufficient exactness."

[26]Ibid., pp. 16-18; propositions one and four.

[27]Ibid., p.21.

[28]Ibid., p.7.

[29]Ibid., p.21.

[30]Ibid., p.19. "Fifthly, the Poles of Magnets are not at their Extremities, but at a little distance from thence; that is, Magnets are not so Magnetical at the Ends, as in the Middle;...."

[31]Ibid., p.19 (continuation of note to page 18).

[32]Boscovich Papers, letter of 20 November.

[33]Knight, Attempt, p.9.

[34]Ibid., p.67; Phil. Trans., xliv (1746), 665.

[35]Attempt, p.69.

[36]Boscovich Papers, Boscovich to his brother Bartolomeo, 14 and 20 November 1760.

[37]Z. Markovic, "Boscovich's Theoria," in Whyte, ed., Boscovich, p.130.

[38]Annals of the Royal Society Dining Club, vol. iv, entry for 5 June.

[39]Boscovich Papers, letter of 14 November.

[40]Ibid., letter of 20 November.

[41]Treatise, p. 7. He was speaking here of artificial magnets.

[42]Ibid., pp.13-14.

[43]Ibid., p.13.

[44]Ibid., p.13.

[45]Ibid., p.13.

[46]J.T. Rutt, Life and Correspondence of Priestley, 2 vols., (London 1831), v.i, p.190, quotes a letter from Priestley to Rev. Joseph Bretland, dated at Leeds, 7 March 1773: "Mr. Michell supposes

that wherever the properties or powers of any substance are, there is the substance itself, something that we call substance being necessary to the support of any properties; but what any substance is, devoid of all properties, we cannot, from the nature of the thing, have any idea whatever; since all the notices that we receive of any substance are communicated to us by means of its properties, and such as bear some relation to our senses, which are the inlets to all our knowledge. And any property may be ascribed to any substance that does not necessarily imply a contradiction, that is, that does not suppose the absence of some other property." R.E. Schofield in A Scientific Autobiography of Joseph Priestley, (Cambridge, Mass. and London, 1966), p.177, quotes this letter with the last sentence ending "...the absence of some other known property."

[47]History of Optics, i, pp.392-393.

[48]See chapter four, section three, where this is discussed in detail.

[49]Treatise, p.7.

[50]Boscovich, A Theory of Natural Philosophy, trans. J.M. Child, (Cambridge, Mass., and London, 1966), pp. 134-135.

[51]See the first two paragraphs of chapter four, section three, and notes.

Chapter Three

[1]Phil. Trans., li, part ii (1760), 466-467.

[2]Ibid., lvii (1767), 234-264.

[3]Ibid., 243, 249.

[4]Ibid., 261-264.

[5]Ibid., 263.

[6]Ibid., 262. Priestley states that Michell later thought that "undulations in the atmosphere" might be primarily responsible for this phenomenon (History of Optics, ii, p. 496).

[7]Royal Society, Canton Papers, vol. ii, p. 79.

[8]History of Optics, i, p.vi. "With respect to the present volume, the reader will easily perceive, that both he and I are obliged to my friend and neighbour the Rev. Mr. Michell, for many original communications; and my obligations to him are much more considerable than will appear on the face of the work. Indeed, several of the observations, will be seen to bear the marks of a more accurate acquaintance with the subject than I can pretend to. With respect to several articles, however, I was so circumstanced, as to be under a necessity of sending them to the press without consulting either Mr. Michell, or any other person whatever; so that, if any mistake be discovered in the work, myself only am answerable for it." (p.vi).

[9]McCormmach, "Michell and Cavendish," 150-151, notes Michell's later suggestion in a letter to Cavendish, 20 April 1784, that light and electricity ("in some degree allied") may not be as much affected by gravity as other kinds of matter; and he concludes that there were probably no imponderables in Michell's system. He notes Michell's discussion of the retardation of light by the sun's gravitation based on Newton, and stresses his "post-Newtonian" connecting of fluids.

[10]History of Optics, i, p.392.

[11]Ibid., i, pp. 392-393.

[12]Ibid.,i, p.387.

[13]Ibid., i, pp. 385-387. Homberg, Mémoires de l'Académie de Paris, (1708) Histoire, 25; Mairan, ibid., (1747) Mémoire, 630. Mairan saw in Homberg's experiment only "...des ébranlemens fortuits & irréguliers, des soubresauts exoités par la chaleur, par la raréfaction & l'explosion subites de l'air qui entouroit ces matières, & point du tout oe mouvement constant & soûtenu qui devroit naître du flux des rayons au foyer du miroir où elles étoient exposées."(426)

[14]Ibid., i, p.387.

[15]Ibid., i, p.385.

[16]Ibid., i, p.389. Both Hardin in "Michell," 44, and McCormmach in "Michell and Cavendish," 150 (see note 9 above), oonclude that Michell believed light to be ponderable, a conclusion with which Priestley would apparently have been in agreement (see note 18 below).

[17]Ibid., i, p.389.

[18]Ibid., i, p.389. Priestley commented: "There seems to be no doubt, however, but that the motion abovementioned is to be ascribed to the impulse of the rays of light."

[19]See Michell's remarks to Benjamin Wilson quoted in the fourth paragraph of chapter six, section two (note 23).

[20]Attempt, p.53.

[21]History of Optics, ii, pp.786-791; Additions, seotion 2, "Of the force by which light is emitted from luminous bodies, and of that which, being lodged at the surfaces of bodies, is the cause of what is generally called their impenetrability."

[22]Ibid., ii, p.787. Priestley continued: "....which proportion is therefore very nearly 28 to 1. N.B. This proportion differs

a little from that given by Sir Isaac Newton in his Principia, both because the apparent diameter of the sun has, since his time, by better instruments, been found somewhat less than he made it, and its distance considerably greater."

[23]*Principia*, 4th ed., (reprinted New York, 1952), p.125. Prop. 39: "Supposing a centripetal force of any kind... it is required to find the velocity of a body, ascending or descending in a right line, in the several places through which it passes, as also the time in which it will arrive at any place; and conversely."

[24]History of Optics, i, pp. 309-311.

[25]Opticks, p.278.

[26]Ibid., p.280.

[27]Ibid., p.282.

[28]Theory, p. 167.

[29]History of Optics, i, pp.308-309.

[30]Ibid., i, p.311.

[31]Ibid., i, pp.393-394.

[32]Opticks, p.373.

[33]History of Optics, i, p.309.

[34]Optioks, p.280.

[35]History of Optics, i, p.309.

[36]Ibid., p.310.

[37]Ibid., p.310.

[38]Michell had referred to Smith's Optioks in his 1767 paper on the probable parallax of the fixed stars.

[39]Smith, Opticks, p.91.

[40]Ibid., p.91.

[41]Ibid., p.91.

[42]In section 2 of the Additions to the History of Optics Priestley spoke of Michell's assumption that the surface powers

probably acted within a distance of one 70,000th or 80,000th part of an inch (pp. 790-791).

[43] Ibid., i, p. 310.

[44] Ibid., i, p. 310.

[45] Opticks, Book Two, Part Three, Prop. VII, pp. 255ff.

[46] Thomas Melvill advanced a similar theory in Phil. Trans., xlviii (1753), 266.

[47] History of Optics, i, pp. 392-393. Schofield, Mechanism and Materialism, p. 245, notes the circumstantial nature of the evidence, and stresses the gap between Baxter's mortar and particles surrounded by powers of attraction and repulsion.

[48] History of Optics, i, p. vi; and see chapter three, note 8, and chapter six, note 3.

[49] History of Optics, i, pp. 390-391.

[50] Ibid., i, p. 392.

[51] Ibid., i, p. 392.

[52] Baxter, Matho, 2 vols., (London, 1740), i, pp. 175,176.

[53] Ibid., i, pp. 223ff.

[54] Ibid., i, p. 223.

[55] Ibid., i, p. 227.

[56] History of Optics, i, p. 392.

[57] Matho, i, p. 175. Priestley wrote that Michell "...found that this author's idea of matter was, that it consisted, as it were, of bricks, cemented together by an immaterial mortar."(History,i,p.392)

[58] Locke, Essay concerning human understanding, 5th ed., 2 vols., (reprinted London, 1965), i, p. 248; book II, chap. XXIII, section 7. P.M. Heimann and J.E.McGuire, "Newtonian Forces and Lockean Powers: Concepts of Matter in Eighteenth-Century Thought," Historical Studies in the Physical Sciences, iii (1971), 253-306, discuss Priestley's debt

to Locke's concept of active powers producing sensation, and the possible influence of Baxter's concept of immaterial powers as agents of God. They also mention Michell's theory of penetrability, but do not note that Michell's transformation of Baxter produced this theory.

[59]Matho, i, p.244.

[60]Rutt, Life of Priestley, i, p.190; see chapter six, note 9.

[61]History of Optics, i, p.393.

[62]See chapter six, note 15.

[63]History of Optics, i, p. 393.

[64]Locke, Essay, i, p.245; book II, chapter XXIII, section 2.

[65]History of Optics, i, p.393.

[66]Priestley, Disquisitions Relating to Matter and Spirit, (London, 1777), pp. 1-2.

Chapter Four

[1]*History of Electricity*, p. xiii. "HITHERTO philosophy has been chiefly conversant about the more sensible properties of bodies; electricity, together with chymistry, and the doctrine of light and colours, seems to be giving us an inlet into their internal structure, on which all their sensible properties depend."

[2]*Ibid.*, pp. viii-ix; (page viii is incorrectly numbered vii in the first edition).

[3]D. McKie, "Joseph Priestley and the Copley Medal," *Ambix*, ix (1961), 13-14.

[4]*History of Electricity*, pp. 7-8, 466.

[5]*Ibid.*, p. 447.

[6]*Ibid.*, p. 447.

[7]*Ibid.*, p. 48.

[8]*Ibid.*, p. 247.

[9]*Ibid.*, p. 463.

[10]*Ibid.*, p. 464.

[11]*Ibid.*, p. 732. "MAY we not infer from this experiment, that the attraction of electricity is subject to the same laws with that of gravitation, and is therefore according to the squares of the distances; since it is easily demonstrated, that were the earth in the form of a shell, a body in the inside of it would not be attracted to one side more than another?"

[12]*Ibid.*, p. 463.

[13]*Ibid.*, p. 450.

[14]*Ibid.*, p. 451.

[15]*Ibid.*, p. 451.

[16]*Ibid.*, p. 488.

[17]*Ibid.*, p. 488. "WHENCE arises the elasticity of the electric

fluid, and according to what law do its particles repel one another? Mr. Price."

[18]Ibid., pp. 722-723. "X. THE WEIGHT REQUISITE TO BRING SOME BODIES INTO CONTACT ASCERTAINED BY THE ELECTRICAL EXPLOSION."

[19]Ibid., p.729. This is their order "with respect to the power of electricity to melt them."

[20]History of Optics, i, p.330.

[21]Ibid., i, p.357.

[22]Opticks, p.370.

[23]Priestley tended to ignore the aether, as did Michell.

[24]Treatise on Light, trans. S.P. Thompson, (New York, 1912), reprinted 1962, pp.3, 10, 16, 18.

[25]Euler, Lettres à une Princesse d'Allemagne, 3 vols., (Mietan and Leipsig, 1770), v. i, pp. 78-79.

[26]Ibid., i, p.79.

[27]Ibid., i, p.86.

[28]Ibid., i, pp. 71-72.

[29]History of Optics, pp. 358ff.

[30]Ibid., i, pp.358, 387-390.

[31]See the account of Michell's experiment in chapter three of this thesis.

[32]Ibid., i, p.390.

[33]Michell spoke in a letter of 1785 of the earth's age in terms of millions of years, Am. Phil. Soc., Michell to Blagden, 27 July 1785.

[34]Phil. Trans., lviii (1768), 343-344.

[35]History of Optics, i, p. 384. It is not known who pointed out Melvill's work to Priestley; Priestley found his two articles useful.

[36]History of Optics, i, p.384.

[37]Ibid., i, p.384; Priestley cited Edinburgh Essays, vol. ii,

p.18.

[38]History of Optics, i, p.393.

[39]Rutt, Life of Priestley, i, p.127. Priestley to Rev. Theophilus Lindsey, 23 December 1770: "I look upon my 'History of Discoveries relating to Vision, Light, and Colours,' to be as good as finished, as little remains to be done besides transcribing, which, however, is necessarily slow and tedious."

[40]R.E. Schofield, "Boscovich and Priestley's Theory of Matter," in Whyte, ed. Boscovich, p. 168. Schofield notes that the Proposals for printing the History published in early 1771 do not mention Boscovich's works in the bibliography; and though this does not prove that Priestley had not heard of Boscovich's ideas before this, it makes it rather difficult to support the more extended claims for Boscovich's influence on the theory of matter advanced in the History, particularly if he had finished a draft by December 1770 (see note 39). The earlier influence of Michell may thus be more crucial than Boscovich's.

[41]J.G.McEvoy and J.E.McGuire, "God and Nature: Priestley's Way of Rational Dissent," History of the Physical Sciences, vi (1975), 325-404, claim Schofield is responsible for the Boscovichean interpretation of Priestley; they emphasize the influence of earlier eighteenth-century thinkers on Priestley's theory of matter, and mention the role of his contemporary, Michell, in passing.

[42]Boscovich, Theory, p.8.

[43]Ibid., p.21.

[44]Ibid., p.21.

[45]Ibid., pp. 20-21.

[46]Ibid., p.134.

[47]Ibid., p.136.

[48]Ibid., p.136.

[49]Ibid., p.19.

[50]Ibid., p.19.

[51]Ibid., p.19.

[52]Ibid., p.19. Boscovich here referred to the last query of the Optioks; but in that query Newton spoke of the attraction of gravity, magnetism and electrioity as "powers" whereby bodies acted upon each other, and "certain active Principles, such as... Gravity, and that which causes Fermentation, and the Cohesion of Bodies." (Opticks, p.401).

[53]Theory, p.19.

[54]Ibid., p. 19.

[55]Ibid., p.19.

[56]History of Optics, i, p.390.

[57]Rutt, Life of Priestley, i, p.190, Priestley to Bretland, 7 March 1773 (see ohapter two, note 46).

[58]History of Optics, i, p.393.

[59]Ibid., i, p.394.

[60]Theory, p. 134.

[61]History of Optics, i, p.391.

[62]Ibid., i, pp. 391-392.

[63]Ibid., i, p.390.

[64]Ibid., i, pp.390-391.

[65]Theory, p. 136.

[66]History of Optics, i, p.391.

[67]Theory, pp. 135-136.

[68]History of Optics, i, p.394; and see above, section ii of this chapter, note 38.

[69]Ibid., i, p.391.

[70]Ibid., i, p.391.

[71]History of Electricity, pp.722-723; and see above, chapter four, section one.

[72] History of Optics, i, p. 392.

[73] Ibid., i, p. 392. Priestley added: "These two philosophers had even hit upon the same instances, to confirm and illustrate their hypotheses, especially those relating to contact, light, and colours." (p. 392). Unfortunately Priestley did not elaborate upon this remark.

[74] See note 40 of this chapter.

Chapter Five

[1] Priestley first composed the *Institutes* at Daventry in 1755; *Memoirs*, ed. Lindsey, p. 78; Rutt, *Life of Priestley*, i, p. 27, note.

[2] *Institutes of Natural and Revealed Religion*, vol. i, (London, 1772), p. 15.

[3] *Ibid.*, i, pp. 15-16.

[4] Locke, *Essay*, i, p. 245; book II, chapter XXIII, section 2.

[5] *Hartley's Theory*, p. xix.

[6] *Institutes*, i, p. 16.

[7] *Ibid.*, i, p. 16.

[8] *Ibid.*, i, p. 38

[9] *Ibid.*, i, pp. 38-39.

[10] *Institutes*, ii, (London, 1773), pp. 73-74.

[11] *Ibid.*, ii, pp. 73-74.

[12] *Ibid.*, i, p. 39.

[13] *Disquisitions Relating to Matter and Spirit*, (London, 1777), p. 8.

[14] *Institutes*, i, pp. 40-41.

[15] *Ibid.*, i, p. 11.

[16] *Ibid.*, i, p. 13.

[17] *Ibid.*, i, p. 4.

[18] *Ibid.*, i, p. 4.

[19] *Ibid.*, i, pp. 156-159. Priestley wrote: "And though, if we had never heard of a future life, we might not have expected it; yet now that we have heard of it, we may be sensible that we should do violence to nature, if we should cease to hope for, and believe it." (p. 159)

[20] *Ibid.*, i, p. 158.

[21] Examination, p. vii.

[22] Locke, Essay, i, Book Two, Chapter XXIII.

[23] Examination, p. xxxvii.

[24] Ibid., p. xxxviii.

[25] Ibid., p. xl.

[26] Ibid., p. xliv.

[27] Ibid., pp. xlviii-xlix.

[28] Ibid., pp. lvi-lvii.

[29] Ibid., p. lvii.

[30] Ibid., p. lix.

[31] Hartley's Theory, p. iii.

[32] Ibid., p. xx.

[33] Institutes, i, p. 11.

[34] Hartley's Theory, p. xx.

[35] Ibid., p. xx.

[36] Institutes, i, p. 158.

[37] Hartley's Theory, pp. xi, xxxviii. Priestley wrote: "And we see, in the case of Father Boscovich, and Mr. Michell, that the very idea of the proper impenetrability of matter may be disputed." (p. xxxviii)

[38] Ibid., pp. iii-iv.

[39] He was "far from being willing to suppress" it. Ibid., p. iii.

[40] Hartley, Observations on Man, 2 vols., (London, 1749), v.i, pp. 12-16.

[41] Principia, Motte's translation, revised by Cajori, (Berkeley, 1934), p. 547. (General Scholium).

[42] Opticks, pp. 345-346. (Queries 12 and 13).

[43] Hartley's Theory, p. xi.

[44] Ibid., p. xviii.

[45] Ibid., p. xix.

[46] Ibid., p. xix.

[47] Institutes, i, p. 15; and see section one of this chapter.

[48] Hartley's Theory, p. xx: "...and that the property of perception, as well as the other powers that are termed mental..."

[49] Ibid., pp. xv-xvii.

[50] Disquisitions, pp. 4-5.

[51] Ibid., p. 5.

[52] Ibid., p. 5.

[53] Ibid., p. 7.

[54] Ibid., p. 352. Priestley wrote: "From the manner of expressing our ideas we cannot speak of powers or properties, but as powers and properties of some thing or substance, though we know nothing at all of that thing or substance."

[55] Ibid., p. 15.

[56] Ibid., p. 15.

[57] Ibid., p. 15.

[58] Ibid., p. 16.

[59] Ibid., p. 7.

[60] Ibid., p. 8.

[61] Ibid., p. 9.

[62] Ibid., p. 16.

[63] Ibid., p. 16.

[64] Ibid., p. 16.

[65] Ibid., p. 17.

[66] Ibid., p. 17.

[67] Ibid., p. 26.

[68] Ibid., pp. 24-25.

[69] Ibid., p. 26.

[70] Ibid., p. 27.

[71] Ibid., pp. 27-28.

[72] Ibid., p. 24. "SECTION III. Of the Seat of the SENTIENT PRINCIPLE in Man, proving that it does not reside in an immaterial Substance." This is the full title given in the table of contents, p. xxxiii.

[73] Ibid., pp. 24-25.

[74] Ibid., p. 114.

[75] Ibid., p. 114.

[76] Ibid., p. 36.

[77] Ibid., p. 37.

[78] Ibid., pp. 37-38.

[79] Ibid., p. 38.

[80] Ibid., pp. 39-40.

[81] Ibid., pp. 43-44.

[82] Ibid., p. 170.

[83] Ibid., p. 170.

[84] Ibid., p. 171.

[85] Ibid., p. 172.

[86] Ibid., p. 44. Priestley cited Matho, ii, p. 212.

[87] Ibid., p. 173.

[88] Ibid., p. 223.

[89] Ibid., pp. 62-63.

[90] History of Opinions Concerning Christ, (London, 1786), i, p. 84.

[91] Disquisitions, p. 51.

[92] Ibid., pp. 50-51.

[93] Ibid., pp. 103-104.

[94] Ibid., p. 105.

[95] Ibid., p. 106.

[96] Ibid., p. 106.

[97] Ibid., p. 108.

[98] Ibid., p. 108.

[99] Ibid., Section IX, pp. 103-113. "Of the Objection to the System of Materialism derived from the Consideration of the DIVINE ESSENCE."

[100] Ibid., p. 111.

[101] Ibid., p. 111.

[102] Ibid., p. 112.

[103] Ibid., p. 354.

[104] Ibid., p. 353.

[105] Ibid., p. 353.

[106] Ibid., pp. 108-109.

[107] Ibid., p. 109.

[108] Ibid., p. 153.

[109] Ibid., p. 145.

[110] Ibid., p. 154.

[111] Ibid., pp. 145-146.

[112] Ibid., p. 109.

[113] Ibid., p. 110.

Chapter Six

[1]"Earthquakes," 62-63, 67.

[2]"Hadley's Quadrant," figure 2.

[3]Rutt, Life of Priestley, i, p. 156, letter from Priestley to Richard Price, dated at Leeds, 23 November 1771. Priestley wrote concerning Price's comments on the draft of the History which Priestley had sent him: "Two of the passages you have censured are in the words of Mr. Michell. What you say is 'by no means rightly expressed,' is his variation of Motte's translation of Newton, which I had before used. I have not so often departed from Newton's own words as you imagine; hardly ever, except to make his phrase more modern."

[4]McCormmach, "Michell and Cavendish," emphasizes Michell's Newtonianism, but finds minor differences and adjustments to the Newtonian philosophy in Michell's work, with perhaps his most significant divergence from the Newtonian tradition being what McCormmach calls his "post-Newtonian" stress on the connections between the various fluids (150-151). See chapter three, note 9.

[5]McEvoy and McGuire, "God and Nature," emphasize the Spinozism implicit in Priestley's monism and necessitarianism, and note the close connection between the concept of necessity and the rationalism which underlay it.

[6]Institutes, ii, pp. 73-74.

[7]Ibid., i, p. 15.

[8]Examination, pp. 5-6.

[9]Rutt, Life of Priestley, i, p. 190, letter to Rev. Joseph Bretland, 7 March 1773.

[10]History of Optics, i, p. 393.

[11]We have seen that Michell found immediate contact possible because of what he considered to be the finite nature of the repulsive powers preventing immediate contact. He also reduced substance to the mere supposed support of properties and the mere product of powers, thus effectively denying it anything more than a mediating role at best. His synthesis of matter and powers also denied the existence of a gap between two types of substance which philosophers from Descartes on had sought to bridge in various fashions. Priestley's acceptance of all of these positions taken by Michell; his own positing of mind as a power of matter, and not a substance of a completely different nature; his denial of the divinity of Christ and his refusal to grant him more than an intercessory or mediating role at most; and his argument that even God might perhaps be of the same substance as his created universe, all tend towards the breaking down of barriers between substances and beings usually thought to be of completely disparate natures. Just as Michell had used the existence of a repulsive power to show that contact and penetration were in fact possible; so Priestley too would argue that some common property was shared by two substances, and then push that argument to the position that the common or mediating property was basic to the existence of each, and thereby transform, whether legitimately or not, the entire nature of the argument. He would thus use mediation at one stage, and then let it disappear if and when he had combined two substances. One might describe his position in a paraphrase of the words of Mackenzie King: "Mediation where necessary, but not necessarily mediation."

[12]Disquisitions, p. 112.

[13]Priestley wrote in the Institutes, i, p. 10, concerning the Epicurean theory of the "fortuitous concourse of atoms,": "...it

may be asked, how could these atoms move without a mover; and what could have arisen from their combinations, but mere heaps of matter, of different forms and sizes. They could, of themselves, have had no power of acting upon one another, as bodies now have, by such properties as magnetism, electricity, gravitation, &c. unless these powers had been communicated to them by some superior being."

The theory of penetrability, with its denial of the absolute solidity which was a central tenet of atomism (including the point-atomism of Boscovich) effectively rejected any atomistic hypothesis; and Priestley argued in addition that the supposition of penetrability advanced by Michell (and, he claimed, Boscovich) "...is much more consonant to the idea which the sacred writers give us of the omnipresence of the divine Being, and of his filling all in all...." (Disquisitions, p. 112)

[14]Schofield, Scientific Autobiography, pp. 169-170.

[15]Alexander, H.G., ed., Leibniz-Clarke Correspondence, p. 35.

[16]Experiments and Observations on Different Kinds of Air, vol. ii, (London, 1775), pp. 146-147. Priestley spoke here of "the two great natural processes of vegetation and animalization." He mentioned in the same work (p. 152) his attempts "...to try what kind of air might be procured from the insensible excrescences of animal bodies, as horn, hair, feathers, &c. which are protruded from the body, and seem, at first sight, to be in a kind of intermediate state between vegetable and animal substances; but they appeared to be more of an animal than of a vegetable nature, i.e. judging by the air which I had hitherto found those substances to give."

[17]Institutes, i, p. 42; "...there is such a perfect harmony and uniformity in the works of nature, and one part so exactly fits and corresponds to another, that there must have been a perfect uni-

formity of design in the whole, which hardly admits of more than one being as the former of it, and presiding over it." (pp. 42-43)

In the same work he wrote: "The designs of such a being as this, who cannot be controlled in the execution of any of his purposes, would be very obvious to us if we could comprehend his works, or see the issue of them; but this we cannot do with respect to the works of God, which are both incomprehensible by our finite understandings, and also are not yet compleated; for as far as they are subject to our inspection, they are evidently in a progress to something more perfect. Yet from the subordinate parts of this great machine of the universe, which we can in some measure understand, and which are compleated; and also from the manifest tendency of things, we may safely conclude, that the great design of the divine being, in all the works of his hands, was to produce happiness." (pp. 19-20)

[18] Schofield, "Joseph Priestley, the Theory of Oxidation and the Nature of Matter," Journal of the History of Ideas, xxv (1964), 285-294, claims that Priestley's rejection of the theory of oxidation was a result of his neo-Boscovichean position that weight was not a basic property of particles. This argument does not take into account Priestley's acceptance of Michell's experiment on the momentum of light and its application to the determination of the weight of the light lost by the sun through emission. Schofield notes that Priestley declares matter to be nothing more than its properties, but his discussion of this fact does not mention that Michell was a likely source for this hypothesis, as for Priestley's ideas on matter in general. Michell's doctrine of attractions and repulsions could have been used to develop a chemical theory, though there seems to be no evidence that Priestley attempted to do so; and the theory of penetrability, the central(and non-Boscovichean) tenet of his theory of matter was not used either, though the theory of powers did play a role.

[19]"Parallax," 242-243.

[20]Michell said that his argument was of a type whereby analogy was used to infer the existence of general law or design; it also depended on the principle that the present arrangement was extremely improbable unless one assumed the operation of such a plan (243).

[21]See chapter six, note 8.

[22]History of Optics, i, p. 393. Priestley's wording suggests the hypothetical nature of Michell's reasoning, in his account: "finding it still necessary, in order to solve the appearances of nature, to admit of extended and penetrable immaterial substance, if he maintained the impenetrability of matter;..." and later: "...he began to think he might as well admit of penetrable material, as well as penetrable immaterial substance..." (the italics are mine; I have omitted Priestley's).

[23]B.M.Add.MSS. no. 30094, f. 86, Michell to Wilson, 22 December 1754.

[24]This experiment is discussed in detail in chapter three, section two.

[25]Experiments and Observations on Air, ii, p. 101; Priestley wrote: "Possibly much greater things might be effected by chymists, in a variety of respects, with the prodigious heat which this [dephlogisticated] air may be the means of affording them. I had no sooner mentioned the discovery of this kind of air to my friend Mr. Michell, than this use of it occurred to him. He observed that possibly platina might be melted by means of it." This work was published in November 1775, two years after Priestley had left Leeds, near which Michell lived at Thornhill.

In a letter to Richard Price, dated 11 November 1772, Priestley mentioned a forthcoming appendix "...containing an account of all the

kinds of air, got by all the acids, from all the metals and semi-metals, most of which I have got from Mr. Michell." (Rutt, Life of Priestley, i, p. 185)

[26]Cavendish Papers, letter from Michell to Cavendish, 2 July 1783.

[27]Foljambe MSS. C/112, Michell to Savile, 23 January 1783; see discussion in chapter one text (note 36).

[28]See chapter one, note 6.

[29]Berks.C.R.O., Hartley Russell MSS., D/EHy O.47, letter from Michell to Savile, 1 February 1759.

[30]Cavendish Papers, Michell to Cavendish, 2 July 1783.

[31]Michell's statement concerning the inverse square law (Treatise, p. 19) is quoted in chapter two, note 25.

[32]Royal Astronomical Society, letter from Michell to Herschel, 12 April 1781.

[33]This dual interest in both the pursuit and application of knowledge was also notable in the career of David Hartley, the elder, the physician and philosopher, who so strongly influenced Priestley, and some of whose projects the elder Savile had supported, (including Saunderson's Elements of Algebra which included a John Michell in its list of subscribers; see chapter one, note 24). David Hartley, the younger, inventor and whig M.P. for Hull, was a close friend of the younger Savile, and Michell and Priestley very probably met and knew him.

[34]Priestley had found perhaps the most cogent statement of a belief in the benevolence of God and the progress and happiness the operation of necessity would bring to man, in the Observations on Man which Hartley had published in 1749. Michell's synthesis of matter and powers, of which Priestley learned about 1770, enabled

Priestley to transform Hartley's system by using a dynamic theory and epistemology of matter to develop a monistic metaphysical system which he beieved to be the most suitable framework for his Christian and rationalist faith.

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