Matter in motion: The problem of activity in seventeenth-century English matter theory

Thesis

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CHAPTER 6

ACTIVE PRINCIPLES AND THE MECHANICAL PHILOSOPHY AFTER THE RESTORATION

In this Chapter I consider successively the ideas on the nature of matter of three major thinkers who put their ideas into print after the Restoration of Charles II in 1660. The first two, Robert Boyle and Robert Hooke, demand attention as the leading English mechanical philosophers of the time, prior to the advent and ascendancy of Isaac Newton. The third, Sir William Petty, was a founder member of the Royal Society and an important member of the 'mechanist school' even though his historical reputation rests largely on other aspects of his career. I have chosen to speak of him here simply because his brief outline of the nature of matter provides an excellent illustration of the thesis I am presenting. The work of all three, I believe, shows quite clearly that the demands of strict mechanism - to explain everything in terms of an inert matter set in motion by an initial impetus from God - were never actually met by seventeenth-century English philosophers. All of them show some capitulation to the notion of unexplained active principles operating
within nature. At the end of this Chapter I argue that although these principles were unexplained they were not considered inexplicable. The scientific method and the epistemological beliefs of these three thinkers were developed in such a way as to make these active principles acceptable to true philosophy as undeniable, everyday experiences. They hope by this means to circumvent the problem of explaining these principles while still avoiding a return to 'occult' qualities.

Before turning to these matters, however, I will consider the other theme which has attracted our attention over the last few chapters, namely the role of ideology in the seventeenth-century scientific revolution. It is the Royal Society which has attracted the attention of scholars who wish to consider the interaction of ideology and science during this period and, for that reason, I concentrate on the Society here. I believe that recent work, particularly that of J R Jacob, has exaggerated the ideological role of the Royal Society, allowing it to stand representative of all natural philosophical endeavour in the Restoration, and seeing it as a primarily ideologically motivated body. Both of these historiographical positions, I believe, go further than the evidence will warrant.
There is now a well-entrenched historiographical tradition that the Royal Society was an institution dedicated to bolstering the Restoration settlement and the re-established episcopalian Church of England. The leading members of the Society chose to do this, it is alleged, by a cunning use of the new philosophy. Cunning was needed to enable the Society to preserve its ostensible status as a scientific rather than a political organisation. The beginnings of this tradition of historical interpretation can be traced back to Robert K Merton's work on the interrelations between science and society in the seventeenth-century. For, although Merton was concerned to establish the Puritan origins of modern science, he used the membership lists of the Royal Society to provide him with a convenient catalogue of the major scientific thinkers of seventeenth-century England. From then on the Royal Society membership has been used to provide evidence for the Puritan, the Latitudinarian, the hedonistic-libertarian, and the royalist-Anglican origins of modern science. The most forceful and the most recent of such efforts can be seen in the work of James R Jacob,
who adopts the view that the Royal Society was liberal-Anglican in its composition but that, in spite of this ostensible conservatism, it was engaged on an active and aggressive effort for 'the Reformation of the World'.

Even this brief summary is sufficient to raise suspicions about the validity of this approach. If the same general evidence can be used to promote a number of wholly different conclusions then that evidence must be insufficient to establish any one of those conclusions. It is not difficult to see why this should be so. Firstly, it is notoriously difficult to categorize a living, individual personality in terms of a necessarily crude distinction between Puritan and Anglican (or even Puritan and non-Puritan!) or Royalist and Parliamentarian. In particular it has proved totally impractical in prosopographical studies to decide who was Puritan and who was not, because the meaning of 'Puritan' itself was as unclear then as it is now.

Secondly, many people changed their political affiliations quite readily for various reasons but most obviously when they expected to gain from the new
affiliation. And people changed their religious affiliations in the same way—a number of Presbyterians, for example, became episcopalian Anglicans after the Restoration settlement. It follows from this that the historian is in grave danger of pigeon-holing a particular thinker in the way that best suits the chosen historiographical model. Robert Boyle, for example, can be, and has been, regarded as a Puritan or a Latitudinarian Anglican.

Another extremely unsound assumption that is made in all this work is that the Royal Society as an institution was the sole representative of science in England at this time. This is very far from the truth. As Michael Hunter has shown, the safest conclusion to draw about the membership of the Royal Society is that it was rather individualistic. It included some distinguished natural philosophers who lived many miles from London and could only infrequently attend meetings, and yet many distinguished natural philosophers resident in the capital itself never joined. Furthermore, in spite of the scorn of men like John Webster in his Academiarum examen there was a good deal of scientific work being carried out in the Universities. And the College of Physicians, often unrecognised as a rival
to the Royal Society, was in fact as much a research institution as the Society itself. Finally it should not be forgotten that the scientific work engaged in and completed by particular members of the Royal Society was not necessarily undertaken as a result of any Royal Society programme or directives. In short, it is nonsense to suppose that any investigation based solely on a consideration of the Royal Society and its members qua members could lead to safe conclusions about the nature of seventeenth-century English science, much less to safe conclusions about its role in the more general notion of 'the rise of modern science'.

Besides, there is a limit to the weight of argument any prosopographical conclusions can bear. In order to show that the natural philosophy of the Royal Society linked in with and argued for a particular religio-political ideology, it will not do merely to show that the members all subscribed to that ideology (supposing that they did). To complete the argument it must be shown how the natural philosophy and the ideology were linked. Subscribers to the Merton thesis, as is well-known, have relied upon
what has been called the 'Protestant work-ethic'. Utilitarian good works could earn a passage to heaven it was believed, and so the Baconianism, millenarianism, and utilitarian schemes of the Royal Society have been pointed out and even, as we have seen, exaggerated.\(^\text{13}\) There is undoubtedly some truth in this but it is a poor generalisation. The whole impetus of the Protestant Reformation was to reject justification by good-works and insist only upon justification by faith. Calvinism, which is more closely associated with 'Puritanism' than any of the other Reformed Churches, was particularly emphatic about this.\(^\text{14}\)

J R Jacob, has adopted the emphasis given by historians like Webster and Hill\(^\text{15}\) to Baconian-millenarian-utilitarian schemes in the Royal Society, and has related these schemes to what he sees as extreme right-wing political endeavours by men committed to the Restoration settlement. For Jacob the ideology of the Royal Society 'was an aggressive, acquisitive, materialistic, imperialistic ideology'. The Royal Society was not engaged upon 'a mere battle over philosophical and religious ideas' for 'the
nature of society and government was at stake'. The natural philosophy of the Society was developed therefore as 'the way to wealth and power'. Specifically, Jacob believes that the corpuscularian matter theory of the mechanical philosophy was the major philosophical device used to promote the Society's ideology.

It is essential for Jacob's case that the Royal Society did have a unified vision of natural philosophy, a corporate belief in corpuscular philosophy. This was not the case. K. Theodore Hoppen in his study of 'The nature of the early Royal Society' has shown that a number of distinguished members did not accept the mechanical philosophy. Elias Ashmole (1617-1692), Thomas Henshaw (1618-1700) and Sir Robert Moray (d 1673), for example, were rather indebted to Hermeticism, Rosicrucianism and other occultist world-views.

Jacob has undoubtedly allowed himself to be misled here by too uncritical a reading of Thomas Sprat's *History of the Royal Society*. Taken at face value (as Jacob has obviously
Sprat's *History* is perfectly explicit about the ideological intentions of the Royal Society. It does indeed suggest that the natural philosophy of the Society can be used to defend the ideology of the state and its Church and that it can help in the accumulation of the wealth and power of the individual entrepreneur and of the state. However, Sprat's book is not so much a *History* as an apologia, written at a time when the fortunes of the Society were at a low ebb. *The History* was seeking to defend the Society and its natural philosophy against charges of subversion, impiety and atheism and, at the same time, to encourage more wealthy men to join (shortage of money being an extremely acute problem). In view of its defensive, apologetic nature, and its desire to attract wealthy patrons it is hardly surprising (or even remarkable) that it should emphasise the role the Society could play in bolstering the new political status quo and in promoting utilitarian profit-making schemes.

The fact that the Society appears in Sprat's book to present a loosely unified natural philosophical outlook with a corpuscularian mechanist slant is simply due to the well-
known fact that John Wilkins (1614-1672) supervised and practically dictated Sprat's efforts. Wilkins himself was, of course, a leading corpuscularian mechanist. Had Sir Robert Moray supervised Sprat's *History* the image of the Society may well have been presented differently. Besides, the dominant feature of Royal Society methodology, which Jacob chooses to overlook or suppress, is its mitigated or constructive scepticism. We have already seen how constructive scepticism could be used to defend the *status quo* for conservative and orthodox thinkers by suggesting a suspension of judgement on controversial matters.

Similarly, Sprat, under the direction of Wilkins, outlined a methodology for the Royal Society which avoided the excesses of dogmatism on the one hand and nihilistic scepticism on the other.

Having repudiated all dogmatic philosophies among ancients and moderns alike Sprat is aware that his sceptical method may be regarded as equally dangerous:

To this fault of *Sceptical doubting*, the *Royal Society* may perhaps be suspected, to be a little too much inclind'd...
But his defence embodies a succinct statement of what Richard Popkin has called 'mitigated scepticism':

They /Society fellows/ are ... as far from being Scepticks, as the greatest Dogmatists themselves. The Scepticks deny all, both Doctrines and Works. The Dogmatists determine on Doctrines, without a sufficient respect to Works: and this Assembly /The Society/, (though we should grant, that they have wholly omitted Doctrines) yet they have been very positive and affirmative in their Works. But more than this, it must also be confess'd, that sometimes after a full inspection, they have ventur'd to give the advantage of probability to one Opinion, or Cause, above another: Nor have they run any manner of hazard by thus concluding...

The Baconian compilation of various natural histories and the enterprise of 'theory-free' experimentation which were the major facets of Royal Society methodology were developed, therefore, as the perfect embodiment of mitigated scepticism, even if they were almost entirely unfruitful and unworkable in practice.

The idea that the Royal Society was founded by a coterie of thinkers who were motivated primarily by 'greed and self-aggrandizement' with aggressive political and imperialist ambitions which led them to develop a natural
philosophy capable of serving those ends is entirely unsupportable from the evidence available even if we were to grant that it is feasible in principle for science to develop in that way.\textsuperscript{31} The aggressive, highly politicized body envisaged by Jacob is highly unlikely to have been regarded, even by the merriest monarch imaginable, as 'court-jesters'.\textsuperscript{32} Clearly, the judgements of Margery Purver that 'the Royal Society was, in fact, ... independent of party', and of Michael Hunter that 'science had a genuine neutrality' are much more faithful to the historical record.\textsuperscript{33} Although perhaps these judgements should be modified a little in so far as the aloofness of the Royal Society from ideological debate made it, \emph{ipso facto}, a \textbf{conservative} body tending to preserve the \textbf{status quo}.\textsuperscript{34}

Before turning to consider the role of active principles in the matter theory of late seventeenth-century England, we should first consider the attitude of Robert Boyle to the ideological use of natural philosophy. Robert Boyle (1627-1691) has been proposed, again by J R Jacob, as the supreme ideologue
of the seventeenth-century revolution in scientific thought. Jacob has argued that Boyle developed his corpuscular natural philosophy in order to promote his particular religious and political ideology.35

According to Jacob, therefore, Boyle, like the Blackloists and Henry More,36 used natural philosophy in order to establish what he believed to be the true faith. However, it has been suggested here that the orthodox philosophical stance just before and after the Restoration was a mitigated scepticism which tended to eschew all attempts to use natural philosophy for ideological purposes. Indeed I have tried to argue that this mitigated scepticism was developed partly as a reaction against the overt ideological use of science by subversive thinkers like the Blackloists or enthusiastic Protestant sects.37 It is my contention, therefore, contra Jacob, that Boyle was so far from being a believer in the dogmatic use of natural philosophy to promote religio-political ends as to be totally opposed to it.

Robert Boyle, the 'sceptical chymist', was always explicit about his scepticism:
Perhaps you will wonder... that in almost every one of the following essays I should speak so doubtingly, and so use often, perhaps, it seems, it is not impossible, and such other expressions, as argue a diffidence of the truth of the opinions I incline to, and that I should be so shy of laying down principles, and sometimes of so much as venturing at explications. But I must freely confess... I have often found such difficulties in searching into the cause and manner of things, and I am so sensible of my own disability to surmount these difficulties, that I dare speak confidently and positively of very few things. 38

Boyle was not simply being modest about his personal abilities but was revealing his deepest beliefs about methodology and epistemology. It was Boyle's belief in the impossibility of achieving certain knowledge that led to his probabilistic approach which was noticed by Laurens Laudan. 39 Boyle felt compelled to admit that his own 'favourite hypothesis' - corpuscularism - could be mistaken:

the same effects may be produced by divers causes different from one another; and it will oftentimes be very difficult, if not impossible, for our dim reasons to discern surely, which of these several ways... she has really made use of to exhibit them... and that it is a very easy mistake for men to conclude, that because an effect may be produced by such determinate causes, it must be so, or actually is so.
Just as such attitudes were likely to lead to a suspension of judgement on political matters or religious controversies, so Boyle refused to commit himself to one or other of the rival theories of matter:

both the Cartesians and the Atomists explicate the same phaenomena by little bodies variously figured and moved. I know that these two sects of modern naturalists disagree about the notion of body in general, ... as also about the origin of motion, the indefinite divisibleness of matter, and some other points of less importance than these: but in regard that some of them seem to be rather metaphysical than physiological notions, ... I esteemed that not withstanding these things wherein the Atomists and Castesians differed, they might be thought to agree in the main, and their hypotheses might ... be looked on as ... one philosophy.

It is Boyle's reluctance to indulge in any sort of theoretical explanation, beyond that of declaring all to be 'matter in motion', that accounts for the 'Baconian' nature of so much of his work: tedious accounts of one experiment after another.

The work of L T More, H G Van Leeuven and R S Westfall amply demonstrate the constructive scepticism of Boyle's epistemology and, consequently, his scientific method so we need
not dwell on it further. 42 Let us turn, then, to consider Boyle's attitude to the ideological use of natural philosophy.

In *Some considerations about the reconcileableness of reason and religion* Boyle quite explicitly warned against reliance on rationality:

our intellectual weaknesses, or prejudices, or prepossessions by custom, education etc, our interest, passions, vices, and I know not how many other things, have so great and swaying an influence on them [the faculties] that there are very few conclusions, that we make, or opinions, that we espouse, that are so much the pure results of our reason, that no personal disability, prejudice, or fault, has any interest in them... 43

In keeping with this warning, Boyle's *Excellency of theology compared with natural philosophy* repeatedly asserts the necessity for revealed religion and denies the possibility of using natural philosophy to prove the truths of religion. 44

Boyle's anti-ideological stance may well derive, at least in part, from his knowledge that the earliest overt attempt to use natural philosophy for ideological purposes was perpetrated by the counter-reforming Catholics, Kenelm Digby
and Thomas White. There can be no doubt that Boyle knew the work of the Blackloists:

Digby had ingratiated himself with Samuel Hartlib in the early 1650s, and is mentioned by Hartlib in a number of his letters to Boyle. 45 The Hartlib circle were very keen to establish a unified church and it may well be that Digby entertained hopes that the Blackloist ecumenical theology would hold some appeal for them. We also know that Boyle harboured strong anti-Romanist feelings from his short-tract, Protestant and Papist, published anonymously during James II's brief reign. 47 However, we do not have to rely on speculation. Boyle illustrates his opposition to the ideological use of natural philosophy in The excellency of theology with an undisguised critique of Digby's arguments for the natural immortality of the soul. 48

Boyle introduces the subject in a way strongly reminiscent of Digby's own introduction to the Two treatises:

If we can prove, by some intellectual operations of the rational soul, which matter, however modified, cannot reach, that it is a substance distinct from the human body, then there is no reason why the dissolution of the latter should infer the destruction of the former,
which is a simple substance, and as real a substance as matter itself, which yet the adversaries (Epicureans) affirm to be indestructible.\textsuperscript{49}

Unlike Digby, however, Boyle denies the validity of this and similar arguments by pointing out that God may have so ordained, that though the soul of man, by the continuance of his ordinary and upholding concourse, may survive the body, yet... it shall be annihilated, when it parts with the body, God withdrawing at death that supporting influence which alone kept it from relapsing to its first nothing.\textsuperscript{50}

Boyle concludes, therefore, that notwithstanding the physical proofs of the spirituality and separableness of the human soul, we are yet much beholden to divine revelation for assuring us, that its duration shall be endless.\textsuperscript{51}

In other words we have to rely upon Scripture not upon natural philosophy.

Boyle takes care to point out to his readers that the instigator of such a dogmatic rationalist pneumatology is not the arch-
dogmatist, Descartes, but Sir Kenelm Digby. The Frenchman, Boyle claims, spoke only as a probabilist on this matter:
And that you may not doubt of this I will give you for it his own confession as he freely writ it in a private letter to that admirable lady the princess Elizabeth... who seems to have desired his opinion on that important question, about which he sends her this answer, 

Pour ce qui est, i.e. As to the state of the soul after this life my knowledge of it is far inferior to that of monsieur (he means Sir Kenelm) Digby. For, setting aside that which religion teaches us of it, I confess, that by mere natural reason we may indeed make many conjectures to our own advantage, and have fair hopes, but not any assurance. 52

So, it would seem that Boyle, like many of his contemporaries, recognised the dangers lurking in all attempts to use natural philosophy to bolster a particular religious or political point of view. Rather than engage upon such enterprises himself, he chose to adopt the cautious stance of the mitigated sceptic. There is no evidence to suggest, as Jacob does, that he allowed his 'social vision' to shape his natural philosophy in order to bring about 'the Reformation of the World'. 53

It may be objected to what I have said that Robert Boyle did write a number of works, such as the *Usefulness of natural philosophy and the Christian virtuoso*, 54 in which he linked his science to theology in a perfectly explicit way. Only by misreading these works
could they be made to support Dr Jacob's case. In fact these works are not so much propagandist as apologetic. It has long been known to historians that the Royal Society and the whole enterprise of the new philosophy were attacked by conservative contemporaries. The major objection to the new philosophy, as we have seen, was the fact that it could be used to promote Roman Catholicism, enthusiasm or atheism. It is hardly surprising, therefore, that Boyle should enter the lists in defence of the new philosophy. In order for his defence to be productive, however, he had to steer a careful course. He could strive to show that the new philosophy was not irreconcilable with the principles of the Christian faith and, providing he was circumspect, he could even venture to suggest ways in which it was a bolster to the faith. Circumspection was essential because any dogmatic rationalism would dangerously backfire. The dogmatic approach could be associated either with what was regarded as Cartesian or Hobbesian atheism, or the Romanism of Blackloists or Jesuits. It is this need for caution which led Boyle to dissociate his own theories even from so seemingly orthodox a figure as Henry More, which we noticed in the previous chapter.
In conclusion, therefore, we can say that the kind of dogmatic propagandist science, which Jacob imposes upon Boyle and the Royal Society as a whole, was really a feature of natural philosophy as it was propagated earlier in the century in the work of the Blackloists and of Henry More. This early background has been completely overlooked by Jacob. By the Restoration a reaction had set in and the cautious low-key approach of fruitful doubt was judged to be the only safe course. Propaganda gave way to apologetics.

In view of the heterogeneous nature of the Royal Society it is absurd to talk about a 'Royal Society matter theory'. In the following sections of this chapter, therefore, we will follow our usual course. We will study the theories of activity in matter of three major thinkers whose work can be held to be indicative of major developments in seventeenth-century natural philosophy.

2. **Robert Boyle, the irresolute mechanist**
In her early work on Robert Boyle and 'The establishment of the mechanical philosophy',
Marie Boas Hall pointed out that motion played a crucial role in Boyle's mechanical philosophy. Indeed Dr Boas Hall went so far as to say that it was the emphasis on the heuristic possibilities of motion and variations of motion which distinguished the seventeenth-century mechanical philosophy from the 'mechanical' philosophy of Democritus and Epicurus. We now wish to take this insight further and suggest that motion played such a crucial role that it led to a fundamental compromise in Boyle's mechanistic philosophy. Like the earlier thinkers we have looked at, Boyle could not develop a strictly mechanistic system of natural philosophy which could explain all physical phenomena. Moreover, it seems that Boyle was well aware of this failure.

*The origin of forms and qualities,* published quite early in Boyle's publishing career, was meant to provide a complete account of his corpuscular matter theory and to demonstrate its explanatory force with regard to natural phenomena. Right at the outset Boyle addressed himself to the question of 'how matter came by its motion'. Here, he took a straightforwardly Cartesian view of it:
the origin of motion in matter is from God... I think also further, that the wise Author of things did, by establishing the laws of motion among bodies, and by guiding the first motions of the small parts of matter, bring them to convene after the manner requisite to compose the world... 62

Later, he even implied (again following Descartes) that matter owed its corpuscular structure to actions of motion: 'motion, variously determined, doth naturally divide the matter it belongs to into actual fragments of parts'. It follows that motion is not part of 'the essence of matter' and that matter can retain 'its whole nature when it is at rest'. 63

However, these pronouncements were far from being Boyle's last words on the subject. His Essay of the great effects of even languid and unheeded motion, we are told, was meant to form a part of The origin of forms and qualities (1666) even though it was not published until 1685, 64 and yet even here uncertainties in Boyle's position begin to appear. It is by no means clear, for example, what Boyle means at the end of the very opening paragraph of this essay where he says:
there may not be divers effects wont to be attributed to occult qualities, that yet are really produced by faint or unheeded local motions of bodies against one another, and that "oftentimes at a distance."\(^{65}\)

Whatever Boyle might mean by producing effects at a distance, it is clear that the 'faint motions' he has in mind are vibratory motions in the particles.\(^{66}\) The implication is that rest is an illusory state brought about by the inadequacy of our senses and is not really to be found in nature. Boyle made this more explicit in his 'Essay of the intestine motions of the particles of quiescent solids'. The sub-title of this essay informs us that 'the absolute rest of bodies is called in question'.\(^{67}\)

In this essay, Boyle now considers, as a feasible alternative to the Cartesian explanation, that 'every particular atom' may have 'an innate and unloseable mobility'.\(^{68}\) After numerous observations of a diversity of phenomena, from the behaviour of unseasoned wood to electrostatic phenomena in diamonds, Boyle concludes:

Having thus made it probable that amongst the parts of such solid bodies, as I have hitherto instanced in, there may not be such a perfect rest, as is generally believed; it will, I suppose, be expected, that I should now draw this consequence from what has been said, that there is no such thing as absolute rest in nature.
And we surely would have expected Boyle to make that conclusion if we did not know that he was far too cautious to come to such a dogmatic conclusion — particularly when it is liable to seem like a vindication of Epicureanism. At the last minute, therefore, Boyle falls back upon his sceptical strategy: 'I shall content myself to say, that it is not either absurd to doubt, whether there be absolute rest or no; nor improbable to think, that there is not...'

Boyle's caution and avoidance of metaphysical problems make an exegesis of this kind rather difficult. Even his attitude to the problem of rarefaction seems to be unrevealing. I have indicated throughout this thesis that the problem of rarefaction provides an excellent example of both the strength and weakness of the mechanical philosophy. On the one hand, the atomist account of rarefaction is immediately intelligible in comparison to all rival efforts, but on the other it seems to demand a concept of repulsive forces operating over the distance between the particles of the rarefied substance. This problem lies at the root of one of Nathaniel Torporley's most cogent criticisms of Harriot's atomism; it led Digby to dismiss any theory
which led to particles of matter standing apart like 'nettes or cobwebbes'; and it caused Henry More to develop a 'fourth Mode' as a new 'property of Substance'.\textsuperscript{70} In view of the fact that Boyle's reputation as a scientist rests largely upon his work on rarefaction and the 'Spring' of the air, he could hardly fail to confront this problem. However, to confront a problem is not to solve it.

Marie Boas Hall argues in her 'Establishment of the mechanical philosophy' that, though Boyle never solved the problem of elasticity, 'he often attacked it'.\textsuperscript{71} This seems to me to be rather an exaggeration. In fact, Boyle nearly always refused to attack and was merely content to recite the possible explanations drawn from Cartesianism or Epicureanism. Dr Boas Hall has suggested that he proceeded in this manner in his writings because 'he knew that his discoveries would receive a wider audience and a quicker acceptance if he did not burden them with theory'.\textsuperscript{72} There is, no doubt, some truth in this but it must also be recognised that Boyle could not provide a convincing explanation of his own. Once again he chose to retreat behind the safe, non-
controversial stance of constructive scepticism.

There are a number of examples of this attitude but the following is one of the clearest statements of it:

to some perhaps it will seem more fit to consider than easy to resolve, how, since the corpuscles of the air are acknowledged to be heavy, and those that remain must be so wonderful thinly dispersed in the cavity of the receiver, they come to be supported and kept, as it were, swimming therein, and do not appear to subside by their own weight, the Materia subtilis (though the presence of that should be admitted) not appearing to have gravity wherewith to sustain them; and the vacuum (if that be supposed wherever the aerial particles are not) being too near a-kin to nothing to be able to oppose their descent; but though something may be suggested about the solution of this doubt, my hast obliges me to leave it as such.  

In spite of Boyle's circumspection about making any definitive statements, however, he does seem to lean towards a kinetic explanation of the spring of the air rather than an explanation based on considerations of structure. He admits the possibility of coiled, Spring-like corpuscles as a sufficient explanation but he seems to prefer the explanatory force of particles in rapid motions. Thus:
though the elastical air seem to continue such /elastic/, rather upon the score of its structure, than any external agitation; yet heat, that is a kind of motion may make the agitated particles strive to recede further and further from the centres of their motions, and to beat off those that would hinder the freedom of their gyrations, and so very much add to the endeavour of such air to expand itself. 75

Boyle concludes, therefore, that there are particles which 'owe their elasticity, not so much to their structure as their motion'. 76

It has to be admitted that so far it is impossible to claim that Boyle believed motion to be innate in matter: he always left the Cartesian option open to him. Boyle's own cautious sceptical approach forces his exegetist to follow suit. Using a typical Boylean circumlocution we can only say that it is not impossible that Boyle believed there to be some sort of activity inherent in matter. 77

However, perhaps a remarkable (and all too rare) piece of speculation which Boyle sent for publication at the very end of his career will allow us to go much further. Using this short tract it may be possible to demonstrate that even Boyle had to rely ultimately upon some form of inherent activity in matter to complete his mechanical
philosophy. At an early stage in his career, almost certainly before 1660, Boyle addressed a letter to Samuel Hartlib about the validity of astrology. The fact that Boyle sent this, along with various other materials, to his publisher for inclusion in _The general history of the air_, which appeared posthumously in 1692, suggests that Boyle still entertained these speculations as plausibilities. This letter has been almost completely overlooked by scholars so far and for this reason, as well as its crucial nature for the argument presented here, I feel justified in examining it closely and quoting it extensively.

At the beginning Boyle expresses his hopes for a theory of the planets 'upon such grounds as are indubitably demonstrable'. Without this 'it is impossible we should assert their several aspects, and the mutual influences and virtues they have (through this) one upon another'. This in turn makes it impossible to be certain about any influences the planets may be having on the Earth. Boyle indicates that he has no interest in astronomy for its own sake but only in so far as it helps us:
for predicting, and for (in some measure) determining, the affections, dispositions, and alterations, that are introduced into several things here, either immediately, or into the air immediately, by reason of the course of these superior bodies. 82

Boyle makes it clear that any effects the planets may have must be 'physical'.

He accepts that astrology has a bad name because of its association with 'superstition and paganism', and the 'manifest mistakes and uncertainty' in its predictions. Furthermore the manner of the operation of the celestial bodies on earthly phenomena is usually considered to be inexplicable. 83 'Notwithstanding all those objections', Boyle insists, 'these celestial bodies... may have a power to cause such and such motions, changes and alterations,... which shall at length be felt in every one of us'. This much is clear to Boyle because of 'undeniable experiments' and 'undoubted observations of physicians'. 84 It is at this point that Boyle introduces the principles of a new speculative philosophy:

It may further admit of a demonstration, for if the extreme motions of physic be generation and corruption, and the mean motions rarefaction and condensation,
allowing then these bodies to have a share in promoting the mean motions, (viz.) of rarefaction and condensation, we shall or may soon be convinced that their effects then upon all other things here cannot but be exceeding considerable.

Boyle immediately embarks upon an explication of these matters.

He disposes of generation and corruption fairly briskly. These represent the termini of all motions - 'for the scope, intentions, or effects of all physical motions are only to one of these ends.' Implicit in this notion is the atomist idea that generation and corruption are reducible to the local motions of the constituent corpuscles of any given body. As these are the termini of motions rather than motions themselves Boyle feels it unnecessary to consider them further. His argument for the existence and nature of his 'mean motions' defies summary:

We must acknowledge there are motions, which nature useth as means, between these two extremes: which mean motions must be as opposite also one to another, as the two extremes. Otherwise we should never be at a certainty, which way nature intends by her motion: otherwise also we must say one and the same course, or one and the same thing in nature, may simply and of itself be the cause of generation and corruption, of life and of death, of hardness and softness, which is absurd and impossible.
Henceforth, rarefaction and condensation are called upon to explain other physical qualities: 'the one answering to heat, the other to cold; the one to hardness, compactness and aridity, the other to gentleness, softness, sweetness, maturity, & c'. And Boyle concludes:

that generation and corruption, rarefaction and condensation is the simplest, plainest, and truest analysis, that can be found in nature, for all physical motions, as unto some of which all motion, purely physical, may (as we humbly conceive) without straining, be immediately referred, and as by and through which all may likewise with as little difficulty be resolved.

The subsequent stages in Boyle's argument become 'curiouser and curiouser'. First of all the new first principles of condensation and rarefaction are linked to astrological influences:

it cannot be denied, but all the affections and dispositions of moisture, heat, cold, drought, the course of all winds, showers, thundering, or whatsoever else is used by nature, to produce these two general and universal effects of rarefaction and condensation, do in great measure, if not wholly, depend upon, and are altogether regulated by, the course, motion, position, situations or aspects, of the superior and celestial bodies or planets.

At this point Boyle considers the means by which the planets and the other celestial
bodies affect these sub-lunary phenomena.

Now the territory becomes a bit more familiar:

... we say, that every planet hath its own proper light: and as the light of the sun is one thing, the light of the moon another, so every planet hath its distinct light, differing from all the other. Now we must either say, that this light is a bare quality, and that the utmost use and end of it is only to illuminate; or that there is no light but is accompanied further with some power, virtue or tincture, that is proper to it; which if granted, it will inform us then, that every light hath its own property, its own tincture and colour, its own specific virtue and power: and that according to the several bodies of light, there are several properties, tinctures and powers; and that as one star differs from another in glory, (according to the apostle) so one star and one planet differs from another in its virtue, in its colour, in its tincture, and in its property.

As with Warner, Digby, and Hobbes at the beginning of his career, Boyle invokes light as the active principle in his system of nature:

those eminent stars and planets, that are in the heavens, are not to be considered by us as sluggish inertial bodies, or as if they were set only to be as bare candles to us, but as bodies full of proper motion, of peculiar operation, and of life; the sun not only shining upon the rest of the planets, but, by his quickening warmth, awakening, stirring and raising, the motions, properties and powers that are peculiar to them.
These powers affect us according to the various angles and aspects they form with one another. For Boyle, these arguments constitute a vindication of the belief in astrology. There is no need to rely upon incomprehensible actions at a distance, Boyle insists, because the 'virtue, or power' is transmitted 'with its light, and is the real property of its light'.

It is worth remarking at this point that Boyle speaks unashamedly of 'astral' or 'solar' natures in his *Suspicious about some hidden qualities of the air* of 1674. Moreover he shows a reverence for the notion of light in his *The aerial noctiluca* (an essay about a luminescent body) of 1680 which is suggestive of a familiarity with the traditions of light metaphysics:

light was the first corporeal thing the great creator of the universe was pleased to make, and ... he was pleased to allot the whole first day to the creation of light alone, without associating with it in that honour any other corporeal thing.

Returning to Boyle's letter to Hartlib, we now find him considering in more detail how the heavenly bodies affect things on Earth. First
of all the air is affected: 'moved, stirred, altered, and impressed by these properties, virtues, and lights, as penetrating each part of it'. The heavenly bodies also affect us more directly:

as our spirits, and the spirits likewise of all mixed bodies, are really of an aerious, etherial, luminous production and composition; these spirits therefore of ours, and the spirits of all other bodies, must necessarily no less suffer an impression from the same lights, and cannot be less subject to an alteration, motion, agitation, and infection through them and by them, than the other, viz the air: but rather, as our spirits are more near and more analogous to the nature of light than the air, so they must be more prone and easy to be impressed than it.

Boyle leaves nothing to the reasoning of his correspondent but spells out the full significance of his theory:

these spirits being the only principles of energy, power, force and life, in all bodies wherein they are, and the immediate causes through which all alteration comes to the bodies themselves; it is impossible therefore spirits should be altered and changed, and yet no alteration made in the bodies themselves: and therefore a less limit or extreme cannot be set to the power or operation, or force of the superior bodies upon the inferior, than what must terminate at length into the very bodies themselves.
Boyle describes a cosmology which undeniably owes more to animistic traditions than to the new mechanistic approach:

as the sun shining on the rest of the planets doth not, as we said, only barely illuminate their bodies; but besides this, through the power, virtue, and activity it hath, doth also raise, excite, awaken and stir up the several properties and dispositions, that are in those several and respective bodies, whereby they are more lively and effectually brought forth upon us; so we are to suppose it is in reference to this our planet, which is the earth, which is not only enlightened, warmed, cherished and fructified by the power, virtue, and influence of the sun, but hath its proper magnetical planetary virtue also fermented, stirred, agitated and awakened in it, which it remits back with the reflected light of the sun; and together with this magnetic planetary property of the earth, which is stirred and raised by the sun, are awakened also the seminal dispositions, odours and ferments, that are lodged in, and proper unto, particular regions or places, which do likewise emit and diffuse through the air, as their several and respective benign (so their several malignant, congelative and fracedonous) natures and qualities.

The rest of the letter is concerned with evidence which Boyle considers to back up his speculations. Boyle seems confident enough to submit 'to the judgement of common experience', indeed he claims that 'things of the greatest confidence do oft-times depend upon the most common observations'. The observations presented by Boyle himself include the 'convulsions, cramps, ... lameness, colds...'
which are caused 'by the mere air' and the stiff neck of an 'ingenious doctor' of Boyle's acquaintance after exposure to the rays of the moon.\textsuperscript{99}

It can hardly be denied that Boyle's 'apology for astrology', as he calls it,\textsuperscript{100} is a remarkable tract. Intensely speculative it is highly uncharacteristic of the Boyle we are familiar with. Indeed, it seems so untypical that the reader may be tempted to dismiss it as an aberration. However, there are a number of considerations which militate against such a dismissal. Firstly the gulf of time between the composition of this letter and its appearance in print suggests that Boyle's attitude towards these speculations did not change fundamentally over his career. The most likely explanation for Boyle's failure to print it earlier is that his cautious undogmatic approach led him to avoid a public statement of such speculative and obviously unmechanical principles. His reputation after all, had been won by long and detailed accounts of experiments and unspeculative compilations of Baconian 'natural histories'. Only in this way could Boyle avoid the pit-falls of being branded as an atheist or a dangerous enthusiast. It
may be that towards the end of his life Boyle felt he could afford to take a slight risk. 101

A further suggestion that Boyle took these speculations seriously can be found in his Cosmical qualities of things published in 1671. 102 Without any knowledge of Boyle's letter 'Of celestial Influences or Effluviums in the Air,' 103 Boyle's definition of 'systematical or cosmical qualities' seems too elliptical to be understood and it is probably for this very reason that this treatise has failed to attract scholarly attention. In view of the foregoing, however, we are better equipped to see Boyle's intentions.

Boyle begins this treatise by reminding his readers that natural bodies interact with one another as a result of their own mechanical qualities (size, shape, motion etc). However, he immediately moves on to suggest there may be other kinds of qualities:

there may be some attributes which may belong to a particular body, and divers alterations to which it may be liable, not barely upon the score of these qualities that are presumed to be evidently inherent in it, nor of the respects it has to those other particular bodies to which it seems to be manifestly related, but upon the account of a system so constituted as our world is, whose fabrick is such that there may be divers unheeded agents, which, by
unperceived means, may have great operations upon the body we consider...104

In other words, as well as the mechanical qualities bodies may also have 'a new set of faculties (or powers) and dispositions' which 'depend upon some unheeded relations and impressions which these bodies owe to the determinate fabrick of the grand system or world they are parts of'. These are what Boyle calls 'systematical or cosmical' qualities.105 It would seem that Boyle has in mind here the sort of alterations and agitations caused in bodies by the heavenly bodies, as described to Hartlib. In the appendix to Cosmical qualities Boyle allows himself to speculate further and to suggest that some natural phenomena may be caused by 'peculiar sorts of corpuscles that have yet no distinct name, which may discover peculiar faculties and ways of working',106 Whatever these 'ways of working' are, it is evident that they cannot be reduced to passive matter set in motion by an external agent. It is clear that Boyle is thinking again of his 'astrological' influences because at one point he refers explicitly to the effects of 'some subterraneal changes, or some yet unobserved
commerce between the earth and other mundane
globes'.

In conclusion, then, we can see that, like
the other thinkers we have examined, Boyle
could not find a satisfactory natural philosophy
within the confines of strict mechanism. His
work on rarefaction and the sping of the air
seems to have played a part in leading him to
develop a speculative system involving the
unexplained energy of light and other cosmic
influences. The fact that this does not take
a more prominent position in Boyle's thought,
the fact that it has not been noticed before,
is due to the more predominant influence upon
Boyle of the cautious, sceptical, non-speculative
Baconian approach. He did not pursue his
speculations too far but preferred to remain irresolute.

3. Robert Hooke, the incongruous mechanist

While outlining for her readers the modernistic
advances of the mechanical philosophy Marie Boas
Hall tells us that before mechanism was established,
'there were sympathies and antipathics, congruities
and incongruities, attraction and hostility'.
After the work of Robert Boyle and Robert Hooke with
the air-pump, however, such notions 'were banished
forever from pneumatics'. And yet, we do not
have to proceed very far into Hooke's first major work, *Micrographia*, in order to find him explaining a phenomenon in terms of 'congruity' and 'incongruity'. His first attempt to define these two dispositions is remarkably un-mechanical:

By Congruity, I mean a property of a fluid Body, whereby any part of it is readily united with any other part, or of any other similar, fluid, or solid body: And by Incongruity a property of a fluid, by which it is hindered from uniting with any dissimilar, fluid, or solid body.\textsuperscript{109}

In spite of this antiquated use of terminology, however, Hooke manages to retrieve his status as a mechanical philosopher. In order to find out the cause of congruity and incongruity, he says, we must discover the cause of 'fluidness'. This, in turn, causes no problem: fluidity is nothing else but a certain pulse or shake of heat; for Heat being nothing else but a very brisk and vehement agitation of the parts of a body... the parts of a body are thereby made so loose from one another that they easily move any way, and become fluid.\textsuperscript{110}

Never at a loss for an ingenious experiment Hooke describes the fluid behaviour of a dish of sand kept vibrating on a 'nimbly
beaten' drum-head. Of particular importance for the concept of incongruity is his experiment involving a coarse gravel-like sand intermixed with a fine sand. During rapid vibration these two spontaneously separate out: 'those [particles] that are of a like bigness, and figure, and matter, will hold or dance together, and those which are of a differing kind will be thrust or shov'd out from between them'. Hooke backs this up by reference to sympathetic resonance in strings, so making it quite clear that he also believes such 'sympathies' have a fundamentally mechanical explanation. Ingenious though these arguments and experimental observations are, the problem (now familiar to us) remains: how can we account for these motions? It is at just this point that Hooke's ingenuity fails him:

Now that the parts of all bodies, though never so solid do yet vibrate, I think we need go no further for proof, then that all bodies have some degrees of heat in them, and that there has not been yet found any thing perfectly cold: Nor can I believe indeed that there is any such thing in Nature, as a body whose particles are at rest, or lazy and unactive in the great Theatre of the World, it being quite contrary to the grand Oeconomy of the Universe.
It rather looks as though Hooke had to take for granted an innate motion in his theory of matter.

If Hooke tried to deny the innate motion of his particles of matter he would presumably have to fall back on a more 'occult' account of congruity or introduce attractive and repulsive forces operating at a distance. Indeed there are slight hints of such an 'occult' view of congruity in spite of Hooke's best efforts. For example, even while demonstrating the phenomenon of congruity by means of vibrating sand, Hooke admits: 'this does not come up to the highest property of Congruity, which is a Cohesion of the parts of the fluid together, or a kind of attraction and tenacity'. The mechanical example of vibrating sand is said merely to 'shadow' congruity and to 'somewhat resemble it'.

But perhaps the most revealing indication that congruity is not so straightforwardly mechanistic as Hooke would like to think occurs when Hooke tries to promote the concept of congruity to a major principle of his natural philosophy - 'a coefficient in the most considerable Operations
of Nature'. We have already seen that in order to explain congruity in mechanistic terms Hooke had to rely upon the concept of an innate heat which, by setting the particles of a body in vibration, gives the body a fluidity which accounts for congruity and incongruity. It is somewhat surprising, therefore, to find Hooke claiming not only that the congruity-incongruity dichotomy accounts for rarefaction and condensation, perspicuity and opacity, refractions and hardness, but also heat and fluidity. There is a fundamental inconsistency here which may well have its roots in the ultimate impossibility of strict mechanism. Hooke's own unease at the turn his speculations are taking is displayed at just this point in his text because he immediately apologises for seeming un-Baconian:

I would not willingly be guilty of that Error which the thrice Noble and learned Verulam justly takes notice of, as such, and calls Philosophiac Genus Empiricum, quod in paucorum Experimentorum Angustiis & Obscuritate fundamentum est. For I neither conclude from one single Experiment, nor are the Experiments I make use of all made upon one Subject: Nor wrest I any Experiment to make it quadrare with any preconceiv'd. Notion.

Once again, as with Boyle, we are confronted by the cautious undogmatic Baconian version of
mitigated scepticism so beloved of the Royal Society. 118

In spite of Hooke's methodological inhibitions we do not have to search far in order to find him talking again in terms of active principles. In view of what we know about the frequency of light as an active principle in seventeenth-century thought, we might expect Hooke's 'Lectures of Light' (read before the Royal Society) to provide a likely source. Our expectations are amply rewarded:

This being that we call Light, sure if any thing may be call'd the Anima Mundi: Its Action being so near of Kin to that of a Spirit, the whole Mass being in an instant acted by it, and made sensible as I may so speak, of what is done in any one Point: So that Light may be said to be tota in toto & tota in qualibet parte,119 possibly with some kind of Plausibleness. And yet after all this we may prove it to be purely corporeal, and subjected to the same Laws that bulky, tangible and gross Bodies are subject to. This may inform us also, how even the very remotest Star, and every one of those indefinite Number of Stars may have an Influence every Moment upon this Ball of the Earth on which we tread, and every one upon every other, and all in Proportion Measure and Harmony, so they were made, and so they are preserved... 120

Light we are told is 'the most operative and most considerable Ingredient of the Universe'. 121

It is:
one of the first and Principal of the Powers of the great System of the World, by which the whole is united and made one; and every one part of that unconceivably great Existence of Material Beings is affected by every other, which may thence not improperly be called one Body, or the only Material or Corporeal Being, distinct from which no other Corporeal being is. 122

Hooke continues in the manner of a Biblical exegetist: at the creation matter was made first, for this is what is meant by 'the double name of Heaven and Earth'. After this God created light, 'so that the first active Power was Light'. 123 This active power, therefore, is completely distinct from matter and is given a separate creation. Unfortunately Hooke's speculations are so wild here that he is once again inconsistent with earlier (and later) positions. For example, elsewhere in the lectures Hooke insists upon the materiality of light 124 while in other places he describes light as a pulse in the medium deriving from the vibratory motions of shining bodies. 125

Light as an 'active principle' appears again in Hooke's speculations about the nature of gravity which arose out of his Discourse_of_the_nature_of_comets. 126 Light is no longer the most active principle in the universe but has to share the honour with gravitation - 'a power
of attracting similar solid Bodies towards their Centres'. It is now light and gravitational attraction together which Hooke takes to be 'the most considerable and the most active in Nature, and those from which the most considerable Effects are produced'. Almost immediately, however, Hooke embarks on an attempt to explain gravitational attraction only in mechanical terms. This effort leads Hooke to declare matter and motion 'to be two single Powers which co-operate in effecting the most of the sensible and insensible Effects of the World'. Just when the reader is beginning to think that Hooke has simply forgotten the previous importance he bestowed upon light and gravity he reintroduces them. Now, they are called 'the two great Laws of Motion, which constitute the Form and Order of the... World'. They are called 'laws of nature' because they derive from the ipse dixit of God. It is worth following Hooke's considerations here in some detail.

Once again Hooke considers the Biblical account of creation and again interprets the creation of heaven and earth as the creation of matter. The fact that the world at this time is said to be 'without form, and void' suggests to Hooke 'that the Mater of Heaven and Earth was yet without any
kind of Motion in it... without any moving or acting Power in it'. In a further explication of his meaning Hooke says the world was 'dark without the Motion of Light, without Form'. Motion is created next when the Bible tells us that 'the Spirit of God moved upon the Face of Waters'. Motion is 'most properly called a Spirit' because the term 'spirit' rightly conveys 'its Power of moving'. The matter is said to be 'impregnated' by the 'second Power Motion' (matter being the first power) which, I submit is suggestive of Gassendist matter theory (matter given innate motion by God) rather than the Cartesian (passive matter set in motion by an initial impetus which is then transferred by impacts in a strictly mechanical way). 130

The two laws of motion then follow from God's dictates: 'Let there be light' needs no explication but 'Let there be an Expansum or a Firmament, and let it divide the Waters from the Waters' is not clear. Our exegetist, however, is convinced that 'this means to signify the second general and grand Rule of Natural Motion, namely, Gravity'. It was this second command which caused 'all those Fluids which were of a Terrestrial Nature, to congregate or gather together into the Mass
of the Earth or Earths; and the other of a more
Celestial Nature, to gather together in the
Sun and Stars'. It follows, according to Hooke,
that all bodies in the world are endowed to some
extent with both of these kinds of motion:
light and gravity. One may dominate over another
but there is no body without gravitation and
no body without 'some degree of Light' even if
it does not show the effects of light.¹³¹

There are more than enough indications in the
foregoing that Hooke found it difficult if not
impossible to formulate a mechanical system of
nature without recourse to an active principle
whether it be considered as an innate principle
within matter or an active principle external
to matter.¹³² However, it is true to say that
Hooke usually tried to give mechanical explanations,
even if he did slip often into speaking in terms
of active principles. It would not do to leave
Hooke without saying something about these
efforts. In particular it is important to
consider Hooke's conception of the aether
which, although usually regarded as a crucial
feature of his natural philosophy (and as
an important notion for mechanical philosophy
in general), has received only passing attention
from scholars.¹³³
The most significant aspect of Hooke's aether which must be grasped at the outset is that it is not identical to Descartes' aether or 'second element'. In fact, Hooke explicitly rejects the Cartesian aether as a 'fiction' and a 'Chimera'. Hooke's aether is essentially passive, far from being whirled about in vortex motions it is described as 'stagnant'. It cannot, therefore be the cause of gravity or light or any form of motion. It is merely the medium through which the effects of gravity and so on are communicated. Hooke rejected any suggestions that gravitational attraction was brought about by the impellant action of material corpuscles. Similarly, he believed in the instantaneous operation and transmission of light and so usually regarded light not in terms of particles but as a shock wave transmitted through a medium. The aether was necessary to his system, therefore, in order to avoid charges of allowing action at a distance.

The real cause of gravity and light (and for that matter magnetism), when Hooke is in a determined mechanistic mood, is the same thing which causes congruity and incongruity,
namely vibration. Once again Hooke relies on his belief that all matter in the universe is vibrating. That is why he wanted to claim that all bodies not only exhibit the 'motion' of gravity but also the 'motion' of light, even when its effect were not apparent.139 Hooke may well have avoided action at a distance, but he can hardly be said to have avoided a concept of active matter. On the contrary, Hooke's theory of gravitation and light involves a systolic-diastolic motion of the heavenly bodies of just the kind that Hobbes rejected:

Suppose then there is in the Ball of Earth such a Motion, as I, for distinction sake, will call a Globular Motion, whereby all the parts thereof have a Vibration towards and fromwards the Center, or of Expansion and Contraction; and that this vibrative Motion is very short and very quick, as it is in all very hard and very compact Bodies.140

It is quite likely that Hooke hoped to account for this universal principle of internal vibrative motions in mechanistic terms but there is no evidence that he ever succeeded in this, nor that he even came close. Hooke himself anticipated the objection: 'How does it appear there is any such Motion in the internal Parts of the Body of the Earth'? His response does not inspire confidence:
To this I answer, that though this be hypothetical, yet that there is some such Motion in those Parts, I shall prove clear enough, when I come to the Explication of Magnetism.

A few lines later Richard Waller, editor of these posthumously published notes, tells us 'The Author breaks off here abruptly.' Hooke never did provide the explication of Magnetism either.

Be that as it may, let us accept for the moment Hooke's universal vibrative motions and see where it leads. It is easy to see that such 'globular motions' could lead to an outward pulse of light, say, spreading spherically outwards and causing various effects by impressing against other bodies. How is it though that the same kind of outward pulse - but this time a gravitational pulse - could draw objects towards the pulsating source? Hooke is nothing if not ingenious. He draws an analogy with a 'tradesman' driving a hammer-head or axe-blade on to its helve. The workman will habitually strike the opposite end of the helve to the head or blade. In spite of knocking the helve downwards the heavy head will rise up firmly on to the handle. The question then arises: why does a light
source not attract? It may be that Hooke would fall back here on his conception that there are different 'Mediums' or different aethers for different phenomena. Not only is there one medium for sound and another for light but another for gravity and another for magnetism. If so then we have to conclude that the gravitational aether acts in such a way as always to bring objects downwards or inwards, the light aether always acts oppositely and the magnetic aether acts both ways under different circumstances. The passive, 'stagnant' claim which Hooke makes for his aethers cannot be maintained simultaneously with such a view.

Our task here should not be merely to test our own critical acumen by finding philosophical inadequacies in Hooke's system of nature. The point is rather to show that in spite of his best efforts Hooke never managed to develop a coherent, strictly mechanistic natural philosophy. The difficulties I have pointed to can hardly have failed to make themselves known to Hooke himself, and Hooke may have been troubled by features I have not unearthed. Once again we have to conclude that the mechanical philosophy, strictly interpreted was inadequate for 'saving
the phenomena' without some principle of activity which remained unexplained. Hooke perhaps believed he could explain his pulsating matter in the Cartesian terms of one initial push to the system by God - there can be no doubt that he was mistaken. Hooke's mechanical philosophy remained incongruous to the end.

4. Sir William Petty, the occult mechanist?

Sir William Petty (1623-1687) made one brief but highly significant foray into the realms of matter theory. In view of the scant attention this work has received from historians of science it seems that Marie Boas Hall has not been alone in dismissing it as 'distinctly occult'.

It is, however, its 'occult' appearance which makes it such an invaluable case study for this thesis. For, as we shall see, Petty used the occult, unexplained powers of gravity and magnetism to account for the motion of his atoms and the forces which he believed must be operating, even over distances, between them. As it stands in its published form, Petty's atomistic hypothesis is short and somewhat elliptical. Nevertheless, a familiarity with the background to his thought makes it possible to reconstruct Petty's intentions and to place his theory within the wider context of
mechanistic traditions. This, in turn, will enrich our understanding of the wider context. Before turning to this, however, we must outline what his theory was.

In 1674 Petty published a *Discourse made before the Royal Society... Concerning the use of duplicate proportion in sundry important particulars.* This is an interesting piece in itself, showing an early knowledge of the inverse square law and its application to practical problems. However, it is the short appendix which provides the focus for our interest. Entitled *A new hypothesis of springing or elastique motions* it is immediately clear that Petty hopes to provide a solution for the problem of rarefaction. Petty indicates just how big a problem this was when he says that he has developed his new theory 'in order to make a breach on this hard Rock in Philosophy, and to chip off a little of that Block which has long lain thwart Us in the way of Our Enquiries'.

The new theory begins with an account of what matter consists of. All things are composed of particles 'immutable in magnitude and figure'. Like Charleton, Petty does not hesitate
to say that 'all juncture of atoms' is due to their 'innate motions'. Moreover,

every Atom is like the Earths Globe or Magnet, wherein are three Points considerable, viz two in the surface called Poles, and one within the substance, called Center, or rather Byas, because in Atoms we consider neither Magnitude nor Gravity.

The byas of one atom 'may have a tendency towards the byas of another near it', and the 'byasses' of many atoms 'may tend to some common point without them'. The outcome of these suppositions is that atoms, 'like a magnet', have two motions: one 'of Gravity' towards the centre of the Earth, and the other 'of Verticity' towards the Earth's poles and the opposite poles of other atoms.

It follows that

All atoms by their motion of Verticity or Polarity, would draw themselves, like Magnets into a straight line, by setting all their Axes in directum to each other; did not the Motion of their respective Byasses towards each other, and towards other Points curb them into a Triangle, whereof the Two Axes of Two Atoms are two sides, and the distance between the Byass of each making the third side: wherefore I call the Polar Motion above-mentioned, the Motion of Rectitude; and the Motion of the Biasses, the motion of Angularity or Curvity, or the Angular
or Curve Motion. I suppose, that all these Motions may be of different Velocities, and that by Contraction and Recollection they balance each other, sometime into seeming rest: I say, seeming, because perhaps there is no rest in Nature. 155

The most immediately striking aspects of Petty's matter theory are, firstly its bold originality and secondly its extremely hypothetical nature. This last point is all the more surprising if we remember that this was read before a meeting of the Royal Society who are alleged to have eschewed mere hypothetical speculations. It will not do merely to write Petty off as a renegade who misunderstood the intentions of the Society. On the contrary, he was a founder member and thoroughly imbued with the collective aims and methods of that central group in the Society closely associated with its prime mover, John Wilkins. 156

In fact, if we consider the background to Petty's short work we can see that it is not such an unprecedented work as it may seem. While the Hypothesis of elastique motions is certainly original it can be seen to fit into a definite tradition (albeit a minor one) of natural philosophy in seventeenth-century England. Furthermore, Petty's hypothetical method is not unique to him but is one example of a recogniseable trend in Royal Society methodology.
We will now look in detail at the background to Petty's work and provide it with its context. This is not meant to detract from Petty's originality or ingenuity but to show that his matter theory should be treated as an important aspect of Restoration science and not dismissed merely as 'occult'. We turn first, then, to consider the minor tradition of physics to which Petty's hypothesis belongs.

It is well known that the Copernican revolution in astronomy stimulated the development of modern physics by forcing sympathetic natural philosophers to provide a physical explanation of how the earth moved, what kept it in motion and so forth. Naturally, most attention has been paid to the modernistic development of inertial dynamics begun by Galileo and culminating with Newton. However, one of the very earliest attempts to account for the motion of the Earth was provided by the Elizabethan physician, William Gilbert (1540-1603).

Gilbert's role in this important enterprise of modern science was pointed out by F R Johnson in his Astronomical thought in Renaissance England. Unfortunately, since Johnson's perceptive study little has been made of this aspect of Gilbert's work. Gilbert scholars have concentrated almost exclusively on the
role of experimentation in Gilbert's
*De magnete* and give the reader the impression
that the development of the experimental
method is Gilbert's only claim to fame.\textsuperscript{159}
However, even a cursory glance at the contents
of *De magnete* will show that the whole thrust
of the book and its culmination in Book VI
are concerned with establishing that the
motion of the earth is physically possible
and, contrary to everyday experience, is
actually probable.\textsuperscript{160}

In view of the failure of other scholars to
discuss this, and the fact that Johnson himself
takes it for granted, it is worth making a
brief digression to show precisely how Gilbert's
argument proceeds. He begins simply by showing
that all magnets or loadstones have two poles
in the same way as the earth and the heavens
themselves.\textsuperscript{161} Even his decision to experiment
with artificially shaped, spherical loadstones
(called *terrellae*) has propagandist intentions!
Gilbert telling us that 'the stone thus prepared
is a true homogeneous offspring of the earth'.\textsuperscript{162}
After a series of chapters dealing with various
details of the magnetic properties of the
loadstone and iron-ore, Gilbert turns to his
'unheard-of view of the earth', advertised in the title of the book, that the Earth is a great magnet. No sooner does he embark on this than he is hinting at the main point of his book:

the loadstone possesses the actions peculiar to the globe; of attraction, polarity, revolution, of taking position in the universe according to the law of the whole.

The magnet as a tiny sample of pure earth displays the same motions as the Earth because it has the same innate principle of motion:

the true earth-matter we hold to be a solid body homogeneous with the globe, firmly coherent, endowed with a primordial and (as in the other globes of the universe) an energetic form. By being so fashioned, the earth has a fixed verticity, and necessarily revolves with an innate whirling motion.

Subsequently, as is well-known, Gilbert takes pains to deny all efforts to explain magnetism in materialistic or mechanistic terms. As Mary Hesse has pointed out Gilbert was 'the first to discuss in detail a true action-at-a-distance', and it is 'to Gilbert's credit that he is not trapped into mechanism as an
explanation of magnetic phenomena'. Instead, Gilbert relies on an essentially animistic explanation involving a world soul. Taken strictly this explanation would be untenable for the mechanistic philosophers who were heirs to Gilbert's work. However, the concept of internal energy or activity, as we have seen, was not untenable. Later thinkers could conveniently forget Gilbert's talk of a world soul and concentrate on his less specific discussions of the active principle in nature:

the magnetic nature is proper to the earth and is implanted in all its real parts according to a primal and admirable proportion. It is not derived from the heavens as a whole, neither is it generated thereby through sympathy, or influence, or other occult qualities: neither is it derived from any special star; for there is in the earth a magnetic strength or energy \( \text{vigor} \) of its own. 169

Elsewhere, Gilbert insists that 'the agent force' in heavenly bodies' abides in \( \text{the} \) bodies themselves', 170 that such forces were implanted in the Earth by the Creator 171 and that motion is 'intrinsic to the earth and natural'. 172

If modern scholars have failed to acknowledge this endeavour as Gilbert's over-riding concern, it was not missed by seventeenth-

century thinkers who shared Gilbert's need for a physical explanation of the Earth's motion. John Wilkins in his *Discourse concerning a new planet* (1640), argued that 'as Nature bestows upon other Creatures (for instance, an Eagle and a fly) Spirits and motive powers, proportionable to their several Bodies: so likewise may she endow the Earth with a motive Faculty answerable to its greatness'. In order to resolve doubts about such motive faculties Wilkins argues 'from those Magnetical Qualities, which all Elementary Bodies do partake of', and draws heavily upon 'the Treatise of Dr Gilbert'.

Similarly, Sir Christopher Wren (1632-1723), discussing the history of attempts to explain the motion of the Earth, tells us that 'Gilbert, who having found an admirable correspondence between his Terrella and the great Magnet of the Earth, thought this Way, to determine this great Question'. And there is surely more than just patriotic jingoism in Wren's assessment of Gilbert's importance. The one deserving of most praise was not
Galileus who labour'd to prove the Motion of the Earth, negatively, by taking off Objections, but Gilbert positively; the one hath given us an exact Account of the Motion of Gravity upon the Earth; the other of the secret, and more obscure Motion of Attraction and magnetical Direction in the Earth; the one I must reverence for giving Occasion to Kepler (as he himself confesses) of introducing Magneticks into the Motions of the Heavens, and consequently of building the elliptical Astronomy...

Wilkins and Wren were clearly sympathetic towards and even influenced by Gilbert's programme to reform natural philosophy and their close friend, Sir William Petty, is in exactly the same tradition. His atoms are Gilbert's *tetrælae* writ small - as small as possible! As soon as he declares the magnetic nature of his spherical atoms he feels totally justified in saying that 'these Atoms also may have each of them such Motions as Copernicus attributes to the Earth'. Like Gilbert, he too points out that the Earth and the heavens have the same three points as his atoms - two poles and a central 'predominant Point'.

Although he makes no explicit reference to Gilbert it must be his theories Petty has in mind when he declares that 'every Atome may move about his own Axis, and about other Atoms
also, as the Moon does about the Earth; Venus and Mercury about the Sun; and the Satellites Jovis about Jupiter &c'.

Gilbert's arguments about the inherent motion of magnets and the Earth form a series of hidden assumptions underlying Petty's own brief suggestions about the innate activity of atoms.

Let us now turn to consider the other unusual aspect of Petty's theory, namely its seemingly flamboyant speculative nature. Considering that the theory was originally read to the Royal Society by one of the leading members, it seems to make a mockery of Sprat's claim that the Society was engaged merely on the collection of 'bare, unfurnished Histories' and that 'compleat Schemes of opinions' were anathema to it. The first point to notice here is that, although Petty speculates freely he is always careful to avoid accusations of dogmatism by speaking only of what may happen if his suppositions are accepted. What is far more exasperating for the modern reader who does not share Sprat's anxiety about philosophical dogmatism, is the fact that
Petty never actually explains quite how his atomic terellae will account for elasticity in matter; nor the 'hardness, fixedness, tenacity, fluidity, heat, moisture, fermentation and the rest' which he also claims can be explained in the same way. By refusing to be explicit Petty has avoided a direct public declaration of a belief in action-at-a-distance. Elasticity is obviously to be explained in terms of repulsive forces acting between the like poles of his atomic magnets and all other phenomena in terms of various dynamic equilibria between gravitational attraction and magnetic phenomena (either repulsion or attraction or 'verticity'). Yet nowhere does Petty actually say so.

Even so, Petty felt justified in making these speculations because no-one could deny that there are attractive forces operating between bodies, either gravitational or magnetic, and repulsive forces do undeniably operate at distances between like poles of magnets. Petty defends his speculations, therefore, by claiming that he is not introducing occult explanations but is relying only on phenomena of common experience. Thus:
My Matter is so simple, as I take notice of nothing in each Atome, but of three such Points as are in the Heavens, the Earth, in Magnets, and in many other Bodies. Nor do I suppose any Motions, but what we see in the greater parts of the Universe, and in the parts of the Earth and Sea.

Again all the motions I fancy in my Atoms, may be represented in gross Tangible Bodies, and consequently may be made intelligible and examinable. 185

Although Petty's theories may seem like an 'occult' retrogression to the unwary modern reader, it is clear that Petty himself believed that he was avoiding the 'Chymerical Speculations' of real occultism and was explaining nature 'in a way which the meanest Member of adult mankind is capable of understanding'. 186

By taking a phenomenalist approach Petty believes he has 'mechanically explicated' the world even though he has used the concept of action-at-a-distance. 187

Once again, it cannot be assumed that Petty was aberrant in his methodology. John Wallis (1616-1703) writing in the Philosophical transactions in 1666 simply insisted upon the interaction between the Earth and the Moon as an undeniable phenomenon:
How the Earth and Moon are connected; I will not now undertake to shew (nor is it necessary to my purpose;) but, That there is somewhat, that doth connect them (as much as what connects the Loadstone and the Iron, which it draws,) is past doubt to those, who allow them to be carried about by the Sun, as one Aggregate or Body, whose parts keep a respective position to one another. 188

Similarly, Robert Boyle, writing in 1672, found it convenient to agree with Archimedes, Stevinus and others who, as he pointed out, 'do not take upon them to assign the true cause of gravity, but take it for granted, as a thing universally acknowledged, that there is such a quality in the bodies they treat of'. 189 Moreover, although Boyle could never satisfactorily explain the spring of the air he pursued his experiments with the air-pump in order to make its springiness an undeniable phenomenon. 190 Robert Hooke, likewise, defended his own supposition that the force of gravity 'is extended to a vast distance upward, even indefinitely' in phenomenalist terms:

this Hypothesis or Assertion which I have laid down, doth not create or suppose any new or unheard of Powers, Operations, Effects or Motions, which are within our reach and command,
which we daily try, see, and find the regular working of.\textsuperscript{191}

These few examples are sufficient to indicate that Petty's speculations were not completely outlandish nor likely to be written-off as occult phantasies by all of his contemporaries.\textsuperscript{192} On the contrary, it is clear that there was a definite move towards accepting the non-mechanical nature of gravity and magnetism; and natural philosophers were resigned to the fundamental inadequacy of strict mechanism. This did not mean a return to occultism, however. It simply meant a wider phenomenalist approach was called-for and, going hand in hand with this, a consolidation of experimentalism rather than rationalism as the correct way to proceed in natural philosophy.\textsuperscript{193}
CHAPTER 7
ACTIVE PRINCIPLES TRIUMPHANT:
ISAAC NEWTON AND AFTER

The next significant development in seventeenth-century matter theory appears in the work of Isaac Newton and there is no disputing the fact that his matter theory relied entirely upon active principles. As Joseph Priestley, writing in 1777, put it: 'The principles of the Newtonian philosophy were no sooner known, than it was seen how few, in comparison, of the phenomena of nature were owing to solid matter and how much to powers'. Newton himself was quite explicit about it. In the preface to the first edition of the *Principia* he indicated that the phenomena of nature:

may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually impelled towards one another, and cohere in regular figures or are repelled and recede from one another. These forces being unknown, philosophers have hitherto attempted the search of Nature in vain...

As we can see from the earlier chapters of this thesis, Newton's judgement was perfectly correct. His immediate predecessors had not been able to account for phenomena (even to the satisfaction of their own less rigorous
criteria\(^3\) unless they too introduced non-mechanical dynamic or kinetic principles into their systems. As one leading Newtonian said:

Although now-a-days the mechanical philosophy is in great Repute, and in this Age has met with many who cultivate it, yet in most of the writings of the Philosophers, there is scarce anything mechanical to be found besides the Name, Instead whereof, the Philosophers substitute the Figures, Ways, Pores and Interstices of Corpuscles, which they never saw; the intestine Motion of Particles, the Collucations and Conflicts of Acids and Alkalis, and the Miracles of their subtile Matter...

John Keill (1671-1721) wrote this in 1701 but, as I hope I have shown, it would have been equally applicable in the 1630s.\(^5\) So Newton's matter theory did not itself mark a new departure. What was new, however, was the open recognition of the need for these active principles. There was a definite shift at the end of the century away from a debate about the necessity for active principles to a debate about whether these principles were external to matter or innate within it.

This last point is well-known and undeniable. There are a considerable number of extensive
studies devoted to Newton's use of active principles, action-at-a-distance, and 'non-mechanical' interparticulate forces, which make any further protracted study here somewhat superfluous. Moreover, many of these studies take the story far beyond the scope of this thesis into the eighteenth and even the nineteenth centuries. However, virtually all of this work takes Newton as its starting point. There has been a tendency to regard Newton as the great genius who realised the futility of strict mechanism and introduced, with great success, new non-mechanical principles to account for the activity in nature. The focus of attention for these historical studies has been the subsequent development of these newly conceived active principles in eighteenth-century science, particularly chemistry. Much less attention has been paid to the possible sources of Newton's non-mechanical matter theory. It would seem that a re-assessment of pre-Newtonian matter theory is required before the influences upon and sources for Newton's ideas can be properly discerned. I hope that this thesis may represent a beginning for such a re-assessment.

In what follows I do not intend to make any specific claims for the influence upon Newton
of any particular author or any particular work. The whole concept of 'influence' is fraught with difficulties and conclusions often have to be left tentative even after the most careful scrutiny and assessment of relevant works. Nevertheless, it will be useful to indicate some of the similarities between Newton's theories about matter and what has gone before. This will, at least suggest possible sources for influences upon Newton and will also serve to round off our survey in a fairly complete way, which would be impossible without considering Newton.

Before turning to an examination of Newton's matter theory, however, we must follow our usual practice and spend some time assessing what role, if any, Newton's theory of matter plays in 'the concerns of the wider society'. That is to say, we must consider the role of Isaac Newton not as a scientist but as a religious and political ideologue.

1. Isaac Newton and the social uses of science

As a result of his fundamental importance for the historical development of science, Newton has had to be singled out by those historians who wish to see scientific development merely
as a specific manifestation of economic or political change. Even as early as 1931 the Russian physicist, Boris Hessen, argued for 'The social and economic roots of Newton's *Principia*.\(^9\) This early study was crude and never really taken very seriously, but more recent studies are considerably more sophisticated and impossible not to take seriously. Foremost among these sociological studies of Newton and his followers is Margaret Jacob's *The Newtonians and the English Revolution, 1689-1720* but a number of closely related works help to make this a significant feature in the historiography of the subject.\(^{10}\) In this section we will briefly consider Newton's role as an ideologue and some of the arguments presented in this literature. My intention is merely to point out that, while such studies are undoubtedly valuable, so far the case put forward by these historians is not proven.

It is well-known that Newton was quite explicit about the relevance of his scientific researches to natural theology. As he told Richard Bentley (1662-1742), 'When I wrote my Treatise about our System, I had an Eye upon such Principles as might work with considering Men, for the Belief of
a Deity, and nothing can rejoice me more than
to find it useful for that Purpose'. Moreover,
it is universally acknowledged that Newton's
own theology depended entirely upon his belief
in a Providential God, the Pantokrator, who
closely supervised His creation. Newton's
theology, therefore, is voluntaristic: God
achieves his designs merely by the exercise
of his will. This voluntaristic theology is
made perfectly explicit in the closing paragraphs
of the Opticks. God, we are told,

is more able by his Will to move the Bodies within his boundless uniform Sensorium and thereby to form and reform the Parts of the Universe, than we are by our Will to move the Parts of our own Bodies.

God's creatures are 'subordinate to him, and subservient to his Will'.

Voluntaristic theology can be traced back at least as far as William of Ockham (c.1300-1350) but it first rose to prominence in seventeenth-century natural philosophy in the works of Mersenne (1588-1648) and Gassendi (1591-1655). Like them, Isaac Newton is most clearly understood as a mitigated or constructive sceptic. As Newton
came to maturity, not only did he thoroughly absorb the doctrines of the mechanical philosophy but he also became aware of the intentions and strategems of natural theology. Like Charleton, Boyle and others in his tradition of natural theology, he recognised the dangers of dogmatism. He clearly recognised, for example, that a particular commitment regarding the cause of gravitational attraction, even if intended to prove the existence of God, could easily be used by the irreligious to promote atheism. Whether the cause of gravity should be explained in terms of some material agent or in terms of an inherent active principle in matter, atheists could seize upon it as an argument for the redundancy of God. Newton preferred to leave the question open:

Gravity must be caused by an Agent acting constantly according to certain Laws; but whether this Agent be material or immaterial, I have left to the consideration of my Readers.

He could justify such an 'un-scientific' suspension of judgement in the time-honoured fashion of voluntarist theologians:

... God is able to create Particles of Matter of several Sizes and Figures, and in several Proportions to Space, and
perhaps of different Densities and Forces, and thereby to vary the Laws of Nature, and make Worlds of several sorts in several Parts of the Universe. At least, I see nothing of Contradiction in all this.\textsuperscript{18}

So, Newton chose to leave some natural phenomena unexplained in order to allow God a certain freedom to operate in the universe. The more phenomena that were left unexplained, the more frequently God's will would have to be invoked as the only explanation.\textsuperscript{19} Although Newton himself is quite explicit in his voluntarism, this aspect of Newtonian natural philosophy is most clearly exemplified by his close follower, Samuel Clarke (1675-1729), in his famous controversy with Leibniz (1646-1716). A number of scholars have characterized this debate as a confrontation between Newtonian voluntarist theology and Leibniz's intellectualist or necessitarian theology (in which God's reason takes precedence over his will) and we need not pursue it here.\textsuperscript{20} Suffice it to say that one scholar has described Newton's natural theology as 'the highwater mark of a long theological tradition centering on the Sovereign Will'.\textsuperscript{21}

If further testimony to Newton's mitigated scepticism is required, consider his reluctance to put anything in print, his obsessive secrecy concerning many aspects of his work, and his
repeated rewriting with only minor changes of virtually all the pronouncements he ever made public (as well as many he never did make public). These aspects of Newton's approach to his work may well derive from a combination of factors, including his somewhat peculiar personality, but it cannot be denied that they all testify to an unwillingness to make a dogmatic commitment. Furthermore, his most protracted discussion of matter theory is presented in the form of queries at the end of his Opticks. His theories are proposed, therefore, not as dogmatic beliefs but as a series of suggestions or questions to be considered and answered by others. Even his famous (notorious?) insistence that 'hypotheses non fingo' can be seen, paradoxically, as a manifestation of his sceptical and undogmatic stance. Newton's claim that he is dealing in facts not hypotheses is another example of the 'phenomenalism' described at the end of the last chapter. It is not, therefore, an example of dogmatism but rather of constructive scepticism. We cannot know the cause of gravity or the cause of the repulsive forces which seem to operate between bodies over microscopically small distances but we can demonstrate that they do exist, either by experimental means or
(in the case of gravity) by mathematical analysis and synthesis. Any attempt to explain the cause of gravity must remain hypothetical and unproveable. Newton, like Wallis and Hooke, preferred to delete all such hypothetical constructs and to speak only of the unexplained force of gravity. As Keith Hutchison has recently argued: 'Occult virtues are acceptable to the constructive sceptic, but only after they have been shaved by Ockham's razor'.

In view of Newton's constructive scepticism it is hardly surprising that his natural philosophy should be taken up (as indeed it was) by the Latitudinarian faction in the Anglican Church. Richard Popkin, Henry van Leeuwen and Barbara Shapiro have all shown that the tradition which Popkin calls 'constructive scepticism' was first introduced into England by Christian rationalists like Chillingworth, Falkland and John Wilkins, in an irenic attempt to resolve sectarian disputes in religion. This approach was then taken up by the 'Christian virtuosi' of the new science (to use Boyle's apt phrase). The relationship between Latitudinarianism and
the new science was, therefore, always close. 30

The moderate, undogmatic religion of the Latitudinarians regarded the epistemology and 'phenomenalist' methodology of the new science as a powerful ally in the war against atheism, deism and (equally) internecine religious disputes. 31

All of this has been so well-established by a number of scholars that it is now virtually undeniable. Recently, however, a number of attempts have been made to extend these arguments and to link the natural philosophy of Newton and his followers quite specifically to the party politics of 'Court Whigs' before and after the Glorious Revolution of 1688. 32 It seems to me that this case has certainly not been proved and that the evidence adduced is insufficient to carry the argument. For example, in a short but suggestive paper, J R Jacob has tried to argue that the natural philosophy of the Royal Society (or, at least, the natural philosophy of some of its leading members) changed during James II's brief reign as the political affiliation of the Society shifted from staunchly Tory support for James to Whig demands for a monarch under a contractual obligation to serve his people. 33 That there
was such a shift in political affiliation after the Glorious Revolution of 1688 is perfectly clear. This is hardly surprising because the Society had its own existence as an institution to preserve and could best guarantee its survival merely by bending with the prevailing wind. Michael Hunter in his study of the same period in the Society's history, after careful sifting of the evidence, concluded that the Society's loyalty 'was always to those in government for the simple reason that there things were achieved... Science and strong government... had a natural affinity'.

However, J R Jacob's attempt to show that the natural philosophy of the Society went through a corresponding sea-change must be regarded as a failure. Although Jacob is able to show that the natural philosophy of the Society was used by 'Tory pamphleteers' (by whom he actually means John Houghton, d. 1705) at the beginning of James's reign, he is quite unable to find any natural philosophical work which can be claimed as giving support to the political views of the Whigs. Jacob tries to fill this lacuna in his argument by reference to Robert Boyle's
The martyrdom of Theodora. This work certainly shows Boyle's dissatisfaction with the authoritarian policies of James II but it says nothing whatsoever about Boyle's (much less the Royal Society's) natural philosophy. The only safe conclusion to be drawn from the evidence therefore, is that science had an autonomy which was sufficiently strong to be unaffected by the contingencies of the Glorious Revolution. 36

Even Margaret Jacob's somewhat more cautious account of the political affiliations of her post-Revolutionary Newtonians makes claims which the evidence will not support. She herself is all too aware that during the bloodless Revolution the Church 'stood on the sidelines', neither supporting nor opposing the invasion of William of Orange. 37 Furthermore, she recognises that although 'the Revolution guaranteed the security of the Church within the politico-religious establishment', the Revolution quite definitely 'denied it the political power or social control it had possessed during the Restoration'. 38 What Margaret Jacob fails to point-out is that the Latitudinarian faction rose to prominence in the post-Revolution Church precisely because
it was more flexible and amenable to the new regime than the more intransigent High Church faction. Dr Jacob does not wish to draw this obvious conclusion because she wants to regard the Latitudinarians as political movers bent on establishing a 'social and political ideology... which in the course of the eighteenth-century became increasingly synonymous with capitalistic enterprise'. Her yearning to see all intellectual activity as disguised politico-economic machinations must also account for her inconsistency in maintaining the capitalistic endeavours of the Latitudinarian-Newtonian Church even though she has pointed to the disgust towards and open rejection of 'rapacious self-interest' and the 'vanity of riches' by the Latitudinarians themselves.

One of Margaret Jacob's main contentions is that the nature of matter was a crucial factor in the political debates of that time. For example, the republican freethinker, John Toland (1670-1722) and Samuel Clarke 'were political enemies', she claims 'who quarreled about the world natural because both possessed profoundly different conceptions of how the world political
should operate'. 41 But once again, all that the evidence suggests is a fear of atheism in Clarke not a fear of republicanism. Even so there is some plausibility in Margaret Jacob's account. 42 There can be no doubt that Clarke was opposed to republicanism and may have felt that by arguing against Toland's natural philosophy he was undermining Toland's political views. If so then Clarke would be in the same position as John Wallis who sought to ridicule Thomas Hobbes's prowess as geometer in order to 'lessen Mr Hobbes's credit in his other writings'. 43 However, unlike Wallis, Clarke never made this motivation explicit and so doubt must always remain.

Indeed, it may well be that Clarke did not aggregate Toland's natural philosophy to his politics because he, unlike Margaret Jacob, was all too aware that there were no hard and fast affiliations between matter theory and political doctrines. Although the radical republican John Toland believed in the innate activity of matter so did Leibniz and he was far from being republican in his sentiments. 44 Furthermore, Newton's natural philosophy was not always interpreted in the way Newton would
have liked and there were a number of 'Newtonians' who believed that gravitational attraction, for example, was an innate principle in matter. Margaret Jacob herself admits that Toland could have taken his theory of matter simply from Newton's writings and even provides evidence that he did. Samuel Clarke opposed all who believed in active matter alike, be they misguided Newtonian, Leibnizian or republican freethinker. The belief in active matter removed the necessity of a Providential God and therefore led to atheism — that was the crucial motivation for Clarke's attacks, not the party politics of his opponent. In other words, Clarke's real bete noire was atheism not Republicanism.

Elsewhere, natural philosophy has been regarded as an important ingredient in the background to the transfer of the British Crown from the House of Orange to the House of Hanover. Steven Shapin, in his essay 'Of Gods and Kings' has tried to extend the Newton-Leibniz dispute from a theological debate into a debate about 'notions of the state and the distribution of authority'. His first strategy to link this rarefied theological debate to what he regards as the 'real' issues is to claim that what was at stake was 'a set of ethical prescriptions about how one was to conduct oneself on earth'. Once again, like those who argue for the Puritanism and science
thesis, Shapin is trying to reduce the argument to one of practical, earthly politics. 49

Most of Shapin's essay consists of an excellent re-statement of the voluntarist - intellectualist theological debate and the extrapolation of this into a disguised but very specific political polemic is dependent on innuendo and assumption rather than argument. What little evidence Shapin does put forward to back up his re-interpretation is insufficient to prove his case. For example, Shapin quotes passages from the Leibniz-Clarke correspondence in which an analogy is drawn between God and a king. Whatever Shapin may say, these analogies cannot be used to show that Leibniz and Clarke 'had radically differing conceptions of kingship' but only that they had differing conceptions of God's role in the universe, which was the acknowledged starting point for the debate. 50

Similarly, a quotation which Shapin interprets as an effort by Clarke 'to reconcile cosmic Toryism with mundane Whiggism', seems to me to be an effort by Clarke to show that he is arguing a theological matter and does not want to be misconstrued as offering any kind of political theory. 51
Steven Shapin is a powerful advocate of what its proponents call 'the sociological reconstruction' of the history of science. It may well be possible to show that Newtonian theological arguments all owe their origins to particular contemporary political doctrines but it must be conceded that the case is not yet proved. It would be interesting to see a 'sociological reconstruction' of Newton's work on scriptural interpretation and church history. Much of this mass of material is obscure but it seems perfectly clear that Newton is engaging in the Reformation endeavour to re-establish the principles of the true faith of the primitive Christian Church. The obvious assumption to make is that Newton regards this to be worth so much labour because the only guarantee of salvation is to follow the true faith. It follows that Newton believed he was transcending the petty squabbles of contemporary politics, even if he realised that a re-establishment of primitive Christianity would have profound political consequences. If the sociological reconstructionists are correct, however, it should be possible to show that Newton's Scriptural interpretations and historical researches were in fact directly
shaped by immediate contemporary political developments.

Perhaps the beginnings of such a sociological reconstruction of Newton's theology are to be found in Larry Stewart's recent article on 'The factions of post-Revolutionary England'. Stewart examines the controversy within Anglicanism over the doctrines of Trinitarianism which was brought to a climax with the publication of anti-Trinitarian views by William Whiston in 1709 and Samuel Clarke in 1712. It is now well-known that Whiston and Clarke became Arians under the influence of Newton and Newton's own Arianism was suspected by many at the time. Stewart's essay very ably demonstrates the fears of leading intellectuals that this form of Newtonian Arianism would lead to deism and atheism. However, his efforts to link this to 'the system of co-ordinates distinguishing city /sic/ from country, Low Church from High, and Whig from Tory' is vague and inconclusive. He concentrates almost exclusively on Roger North as an exemplar of the Tory opposition to Newtonianism but all the quotations he gives merely indicate a fear of atheism on North's part. When Stewart wishes to extend his claim to embrace political
differences we are merely told that political opposition 'is revealed in the many volumes of his _North's_ crabbed writings which have survived.'

It should be clear from this that, in spite of the efforts of Margaret Jacob, Steven Shapin and others, the case for an affiliation between Newtonianism and a particular political faction in post-Revolutionary England is not proven. As Margaret Jacob herself points out: 'In the hands of the unorthodox almost any philosophical system could be made ungodly'. Similarly, in the hands of the orthodox almost any philosophical system could be made godly (or ungodly!). This being so, it is not possible to make any valid statements about the correspondence between Newtonian natural philosophy and a particular political faction in the England of the late seventeenth and early eighteenth centuries. That there was a deep rift between voluntarist and necessitarian systems of theology cannot be denied, and what this reduced to, for both sides, was a fear of atheism. This is now a well-established feature of seventeenth-century historiography which has generated much excellent work. The more recent attempts to reduce this theological debate to a disguised
debate between contrasting political ideologies has yet to prove itself.\textsuperscript{59}

2. Matter and activity: Newton and after
Throughout this thesis I have argued that the mechanists' dream of explaining all natural phenomena in terms of matter in motion was always fundamentally problematic. While seeking to avoid the extremely trenchant and well-entrenched arguments against the ancient matter theory summed-up in terms of 'atoms and the void', seventeenth-century natural philosophers chose to speak instead of 'matter in motion'.\textsuperscript{60} The problem that then confronted them was how to account for the motions. As I have shown in the foregoing, only Hobbes produced a strictly mechanistic system which, like that of Descartes sought to explain all motions in terms of the conservation and transference of an initial push provided by God. All the other major English natural philosophers seem either to have despaired of such a strictly mechanical system on scientific grounds or to have deliberately repudiated it on religious grounds.\textsuperscript{61} Isaac Newton's insistence upon active principles does not, therefore, represent a new departure for the mechanical philosophy. Furthermore,
although Newton's matter theory can be regarded as the 'high-water mark' of the voluntarist theological tradition, it must also be seen as the culmination of the more strictly scientific endeavour to solve the perennial problem of activity which bedevilled the new mechanical philosophy.

In Newton's writings active principles are often equated with the concept of force. I have shown that the problem of extreme rarefaction and the 'spring' of the air always defied explanation in strictly mechanical terms. Among Newton's very earliest speculations, the Quaestiones quaedam philosophicae written in the 1660s, Newton concluded that there must be repulsive forces operating between the particles of matter because air is 900 times less dense than water and can be expanded at least a thousand-fold. Newton returned to precisely this problem sometime between 1673 and 1675 in a short manuscript fragment entitled De aere et aethere. This takes as its starting point the remarkable property of extreme rarefaction and condensation of the air. As in his earlier speculations in the
The particles of air are assumed to repel one another. Newton is reluctant to 'dispute' about the cause of this repulsion but offers some suggestions:

The intervening medium may give way with difficulty or not suffer itself to be much compressed. Or God may have created a certain incorporeal nature which seeks to repel bodies and make them less packed together. Or it may be in the nature of bodies not only to have a hard and impenetrable nucleus but also to have a certain surrounding sphere of most fluid and tenuous matter which admits other bodies into it with difficulty.

It should be noticed that Newton does not yet invoke the direct operation of God. His second possibility is, however, remarkably close to Henry More's explanation in terms of the 'essential spissitude' of natural spirit. Even Newton's account of the expansion of air by heat, which he deals with subsequently, is not strictly mechanical. Although he suggests that heat sets the particles vibrating, it is the repulsive force which accounts for the expansion. The repulsive sphere of influence is able to operate over a larger distance because its source, the particle, moves over a bigger area.
This short exploration of matter theory also provides the earliest references to aetherist explanations to be found in Newton's work. It is tempting to suppose that Newton turns to aetherist explanations in order to provide a more mechanist groundwork for his matter theory and to avoid using the concept of action-at-a-distance. However, as Rupert Hall and Marie Boas Hall have shown, such an interpretation cannot stand up after close scrutiny of the texts. The aether itself, described in De aere et aethere as a 'more subtle air' (aer subtilior) and 'the spirit of air' (spiritus aeris), is composed of particles which repel one another at even greater distances than do air particles. Newton's speculations on the nature of the aether were actually made public in 1675 when he reluctantly sent his Hypothesis of light to Henry Oldenburg to be read before the Royal Society. Here again the aether is likened to air: 'of the same constitution with air, but far rarer, subtler and more strongly elastic'. In a subsequent letter to Oldenburg, in which Newton tries to qualify one or two points in his Hypothesis, he refers to the aether as 'some kind of humid active matter'. 
Three years later, in response to a request from Robert Boyle, Newton refined his notion of an aether with mutually repulsive particles and explained how it could account for the fact that a fly walks on water... without touching the water; that two polished pieces of glass are not without pressure brought to contact, no, not though the one be plain, the other a little convex; that the particles of dust cannot by pressing be made to cohere, as they would do, if they did but fully touch; that the particles of tinging substances and salts dissolved in water do not of their own accord concrete and fall to the bottom, but diffuse themselves all over the liquor... Also, that the particles of vapours, exhalations, and air, do stand at a distance from one another, and endeavour to recede as far from one another, as the pressure of the incumbent atmosphere will let them: for I conceive the... atmosphere, to be nothing else but the particles of all sorts of bodies of which the earth consists, separated from one another, and kept at a distance by the said principle. 71

So, as the Halls and J E McGuire have pointed out, the purpose of Newton's aether was not to excise the notion of action-at-a-distance but merely to provide a single reductionist principle of active matter. In De_aere_et_aethere and in later writings like De_natura_acidorum, and even the Principia, all matter is endowed with the active power of repulsion (or attraction)
while in his aether speculations, only the aether is active while all other manifestations of matter are inert and subject to the forces applied by the circumambient aether. However, in a very real sense this effort at reductionism was counter-productive. The supposition that there are interparticulate forces can be defended by analogy with the forces, such as gravity and magnetism, which can be seen to operate between gross bodies. These forces, then, can be said to be 'inferred from the phenomena or at least... directly related to the phenomena'. However, to introduce the concept of an aether in order to explain what seem to be interparticulate forces is to make a completely ad hoc assumption.

After the letter to Boyle, Newton seems to reject all aether theories and to rely on a multiplicity of interparticulate forces until the second English edition of the *Opticks* in 1717. At this time he added eight 'Queries' (17-24) which were concerned with aether speculations. Once again the speculations are all concerned with a 'force aether' which is described as 'elastick and active', and they cannot be seen as an attempt to
Apart from these aether speculations, Newton's theory of matter always involved the concept of interparticulate forces acting across the distances between particles 'in which force', as Newton himself puts it, 'their Activity consists'. The details of this aspect of Newton's matter theory are easily accessible in the 'Queries' appended to the Opticks. This is clearly seen in the opening words of the final Query (31): 'Have not the small Particles of Bodies certain Powers, Virtues, or Forces, by which they act at a distance... for producing a great part of the Phaenomena of Nature?'

Moreover, these ideas have received such close attention from other scholars that little further comment is required.

There is, however, one detail which I believe my researches have illuminated. On more than one occasion Newton, in seeking to account for the extreme tenuity and porosity of some substances, envisages a net-like structure for those substances:

Certainly the rarity of water cannot be explained on common hypotheses.
One must have recourse to a certain wonderful and exceedingly artificial texture of the particles of bodies by which all bodies, like networks (more retium), allow magnetic effluvia and rays of light to pass through them in all directions and offer them a very free passage... Salts form regular figures in congelation and certain of these such as nitre and sal ammoniac are always transformed into branches. Why should it not be that the first seeds of all things coming together in net-like figures (figuras retiformes) by the force of nature...

This fragment appears in a draft addition to the Principia written sometime in the 1690s. Similarly, in a partial draft of the Preface to the Principia, written in the spring of 1687, he speaks of the aggregation of particles in texturae retiformes to form gross bodies. At about the same time he wrote a draft Conclusio which contains a similar model of the structure of matter:

Particles will not collect together in the composition of natural bodies like a heap of stones, but they coalesce into the form of highly regular structures almost like those made by art, as happens in the formation of snow and salts. Undoubtedly, following the laws of geometry they can be formed into very long and elastic rods, and by connection of the rods into retiform particles (particulas retiformes),...
R S Westfall, in his recent study of Newton's life and works, *Never at rest*, suggests that Newton developed this idea as a result of the alchemical work in which Newton produced a chemical substance known to alchemists as 'the net'.\(^{80}\) The alchemical net, however, was meant to provide a means of separating sulfureous principles from mercurial principles.\(^{81}\) It does not seem to represent a symbol of the structure of matter. Furthermore, when Newton tried to produce net like chemical structures in his laboratory he clearly did so, as Dobbs has shown, in order to 'extricate' the 'fat /sulfurous/ fishes' and leave the 'silvery fishes' of mercury.\(^{82}\) It is difficult to see, therefore, why Westfall should link the 'retiform particles' which are invoked to account for rariformity, to the alchemical 'net' which seems to serve an unrelated function.

The real reason for Newton's insistence that matter may be structured in networks is, I think, much more likely to be a response to Sir Kenelm Digby. It may be remembered that Digby rejected the atomist view of matter and the Concept of void because
if such vacuities were the cause of rarity, it would follow that fluid bodies being rarer than solid ones, they would be of themselves standing like nettes or cobwebbes: whereas contrariwise we see their natures are to runne together, and to fill up every little creek and corner...

It is well-known that Newton had read Digby's Two treatises and absorbed at least some of his ideas. It seems quite likely, therefore, that Newton's efforts to account for the extreme tenuity of matter would remind him of this undeniably cogent objection. If so, then Newton's response is entirely understandable. He simply disarmed Digby's objection by affirming that the particles of matter may well be 'standing like nettes' because of their texturae retiformes.

The fact that Newton's speculations along these lines were ultimately rejected by him and never published provides us with a reminder that Newton never really arrived at a definitive matter theory. Like Boyle and Hooke, he too made several proposals but never managed to arrive at a firm conclusion. His thoughts on matter theory are summarised in the 'Queries' at the end of the Opticks but, as the Halls have pointed out, they are 'rarely definite' and 'on occasion inconsistent'. The problems involved in the activity of matter were so
great that even Newton had to confine himself to the query form, pending 'a farther search to be made by others'. 86

The story of that 'farther search' has been well documented by Metzger, Thackray, Schofield, Heimann, McGuire and others. 87 Needless to say, the details of the developments in eighteenth-century matter theory are extremely complex. Some thinkers took up Newton's aether speculations, while others relied upon inter-particulate forces; some chose to use repulsive and attractive forces in their explanations while others used only attractive forces. Some wanted to emphasise the direct activity of God in the universe while others chose to interpret Newton's ideas as sanctioning the belief in activity as an innate property of matter. 88

In spite of this diversity there has been a tendency to see the ideas of men like Stahl, Boerhaave, Priestley, Boscovich, Hutton and many others, even including Faraday in the nineteenth century, as stemming from a uniquely Newtonian tradition. 89 One or two recent works have tried to correct this monolithic approach but with little success. 90 The major reason for the failure of these
efforts is that, until now, little has been said about Newton's own antecedents. The often subtle distinctions between eighteenth-century thinkers simply have to be attributed to the fact that those thinkers have taken up different aspects of Newton's original speculations because, as Thackray and Heimann have admitted, nothing is known about earlier thinkers who may have influenced Newton and subsequent natural philosophers. I hope that the materials presented here may serve to show that notions of active principles could have been gleaned from pre-Newtonian writers and so serve as a stimulus to further research in order to refine the current classification of post-Newtonian writers as so many Newtonians.

3. Newton and the tradition of light metaphysics

I have repeatedly referred to the tradition of light metaphysics in which light is regarded as an active and formative principle in the universe, a direct emanation from God and the closest analogy to God's modus operandi in the physical world. The tradition is essentially neo-Platonist in its origin and development, and the influence of neo-Platonist ideas on
Newton (largely from Henry More) has long been acknowledged. If my suggestion that light appears in all the major treatments of the mechanical philosophy as an active principle is correct, then we should certainly expect to find it in Newton's work. I want to end my survey, therefore, by testing my hypothesis in this particular way. Once again, the material I am drawing upon is all well-known to Newtonian scholars, nevertheless, it has never been put into the context of the neo-Platonic tradition of light metaphysics.

I want to begin not with Newton's direct statements about light but with his attempts to define the nature of space in one of his very earliest scientific writings, the De gravitatione et aequipondio fluidorum. Here, Newton explicitly declares space to be 'the emanent effect (effectus emanativus) of an eternal and immutable being'. A little later, considering the possibility of an intermediate 'world soul' between God and the world closely akin to Henry More's spirit of nature, Newton reiterates his belief in an emanationist metaphysic: 'the world should not be called the creature of that [world] soul but of God alone, who creates it by constituting
the world soul of such a nature that the world necessarily emanates from it.\textsuperscript{95} This seemingly remarkable notion is totally unremarkable within the tradition of light metaphysics. Moreover, a number of other ideas about the nature of space and body which Newton propounds in this manuscript are ultimately derived from the writings of the neo-Platonist, Francesco Patrizi (1529-1597), a leading figure in the Renaissance promulgation of emanationist metaphysics.\textsuperscript{96} Newton's alchemical studies are also clearly indebted to neo-Platonic (and Hermetic) traditions. Recent commentators on this aspect of Newton's works have persuasively argued that Newton embarked upon his alchemical studies in order to find the active principles which he believed to be inherent in matter.\textsuperscript{97} In one famous manuscript, known by its incipit 'Of natures obvious laws and processes in vegetation',\textsuperscript{98} light appears as a principal contender for the most active power in nature:

Note that tis more probable ye aether is a vehicle to some more active spt & ye bodys may bee concreted of both together, they may imbibe aether as well
as air in generation & in yt aether ye spt is intangled. This spt perhaps is ye body of light because both have a prodigious active principle both are perpetuall workers. 99

Westfall dates this manuscript from 1669 and sees it as prefiguring some of the ideas in Newton's 'Hypothesis of light' of 1675. 100 Much of the Hypothesis does clearly derive from alchemical traditions and does not directly concern us here. 101 However, it is also replete with ideas that derive straight from emanationist metaphysics. 102 It should be noticed that although Newton's 'Hypothesis of light' concerns itself with prolonged discussion of the aether, light is not regarded as merely a pulse or shock-wave within that aether. Light is 'neither aether, nor its vibrating motion' but is a material substance 'capable of exciting vibrations in the aether' in the way a stone excites vibrations in pond water. 103 A ray of light is said to consist of 'unimaginable small and swift corpuscles... urged forward by a principle of motion'. 104 This principle of motion may well be inherent: 'God, who gave animals self-motion beyond our understanding, is, without doubt, able to implant other principles of motion in bodies, which we may
understand as little'. This self-active light can, accordingly, set up vibrations in the aether: 'For it is plain by the heat, which light produces in bodies, that it is able to put their parts in motion, and much more to heat and put in motion the more tender aether'. These vibrations in the aether may then bring about the effects on other bodies which Newton has already expounded and which could, he claimed, account for 'the whole frame of nature'.

The culmination of these ideas can be seen in the 'Queries' in the Opticks. Indeed, the fact that Newton chose to supplement his Principia with a book on the nature of light is in itself suggestive that Newton believed light to hold some important cosmological significance. Query 5 takes off from the earlier Hypothesis but, omitting the aether, suggests that light may directly act upon bodies to start their parts vibrating.

Query 30 asks:

Are not gross Bodies and Light convertible into one another, and may not Bodies receive much of their Activity from the Particles of Light which enter their Composition?

There is even a suggestion, in Query 11, that the Sun and stars are perpetual sources of
light and heat which thus provide a constant source for the active principle of light:

Do not great Bodies conserve their heat the longest, their parts heating one another, and may not great dense and fix'd Bodies, when heated beyond a certain degree, emit Light so copiously, as by the Emission and Re-action of its Light, and the Reflexions and Refractions of its Rays within its Pores to grow still hotter, till it comes to a certain period of heat, such as is that of the Sun? And are not the Sun and the fix'd Stars great Earths vehemently hot, whose heat is conserved by the greatness of the Bodies, and the mutual Action and Reaction between them, and the Light which they emit...

In this way Newton provided as mechanical an explanation as was possible for the perpetual working of the sun. It should be remembered that Digby's and Hobbes's early systems also relied on the perpetual working of the sun, but there it remained completely unexplained. The sun as a perpetual source of activity in the universe was also fundamental to the philosophy of John Hutchinson. Peter Heimann has seen this belief as deriving from Newton's work but in view of Hutchinson's distaste for the Newtonian system this seems unlikely. Nor
can it derive from Boerhaave, as C B Wilde has shown. It may be inspired, however, from a knowledge of Digby's Treatise on body but this demands further research. James Hutton also invoked the sun as the major perpetual source of activity: 'without the influence of the sun, this world would remain an useless mass of inert matter'.

Light as a self-active and therefore perpetually activating principle in the universe is a common theme throughout eighteenth-century natural philosophy. It occurs not only in the work of Hutchinson, Boerhaave, and Hutton but also in Bishop Berkeley's Siris, and the matter theories of Joseph Priestley and William Herschel as well as a host of less well-known writers. Again, there has been a tendency to trace these ideas back only as far as Newton but, as should now be clear, they may well derive directly from earlier seventeenth-century thinkers.

It cannot be denied, anyway, that Newton, like the other natural philosophers we have looked at, recognised the usefulness of the
auto-diffusive, self-active concept of light as an explanatory device for the mechanical philosophy. In the effort to explain phenomena in terms of 'matter and motion' light was invaluable because it could supply both terms. The use of light in this way, as we have seen, was a common feature of English mechanical philosophy ever since Thomas Hobbes adopted it from the ideas of Robert Grosseteste, Roger Bacon and his contemporary, Walter Warner. At the very end of the *Opticks*, Newton declared:

I have only begun the Analysis of what remains to be discovered about Light and its Effects upon the Frame of Nature. But it would seem that the analysis had actually been begun many years earlier by Walter Warner and Thomas Hobbes.
CONCLUSION

The seventeenth-century attempts to forge a new philosophy, in which all physical phenomena were explained in terms of matter and motion, required a metaphysical account of the origin and preservation of motion. Some of the efforts to provide this metaphysical foundation have been examined in this thesis,¹ and I conclude that the all too frequent assumption among historians that the mechanical philosophy relied exclusively upon a concept of matter as totally inert and passive is, at best, inadequate and, at worst, totally misleading.

This simplistic account of the new matter theory effectively ignores the philosophical aptitude of the natural philosophers who tried to establish the new philosophy. Mary Hesse in her classic study in the philosophy of science, Forces and fields, has pointed out that even Descartes 'slipped something other than extension into his conception of matter' because motion 'has to be thought of as a mode of body as fundamental as shape or size, and it is this that leads him to his statement of the law of inertia'.² Part of my argument in this thesis has been that even this concession to the fundamental ontological status of motion was regarded by the English thinkers we have looked at as inadequate for a comprehensive account of physical phenomena. The
Cartesian version of the mechanical philosophy, which I have referred to as 'strict mechanism', was never really accepted by any major English natural philosopher.

In fact, matter was usually considered to be inherently active, containing an internal principle of motion or some kind of innate 'virtue' or 'power'. Needless to say the 'scientific' and philosophical problems, which had to be overcome before the nature of such principles could be discovered, remained insurmountable. It was partly the recognition of this inscrutability, I have argued, that led to the development of and emphasis on the experimental method. Experimentation could confirm the existence of action at a distance, and repeated observation could suggest the incessant motions of matter, even if neither technique could establish the causes of such phenomena. This pragmatic approach to natural philosophy was summed up by Sprat in the History of the Royal Society:

It is probable, that he, who first discover'd, that all things were order'd in Nature by Motion; went upon a better ground, then any before him. But now if he will onely manage this, by nicely disputing about the Nature and Causes of Motion in general, and not prosecute it through all particular Bodies, to what will he at last arrive, but onely to a better sort of Metaphysicks? And it may be, his Followers, some Ages hence, will divide his Doctrine into as many distinctions as the Schole-men did that of Matter and Form. Metaphysics, Sprat is suggesting, will bring no ultimate
benefit to natural philosophy - it is much better to 'prosecute' the new philosophy by particular investigations of all kinds of body.

Philosophical difficulties were not the only factors shaping the new methodology, however. I have repeatedly emphasised the role of mitigated scepticism as the fundamental approach of all but extreme radical or subversive thinkers to all areas of intellectual debate. The approach of fruitful doubt was promulgated, by what we can call the orthodoxy, not only because it was fruitful but also because it was safe. Dogmatism was associated with Roman Catholicism, or sectarian 'enthusiasm' and any kind of dogmatic conclusion, it was realised, could be used to promote a particular kind of religious, irreligious or political ideology. I have suggested that the orthodox awareness of such abuse of natural philosophical argument was partly stimulated by the realisation that Sir Kenelm Digby and Thomas White were using their dogmatic mechanical philosophy, in Henry Stubbe's words, 'to seduce the English to the Apostaticall Church'. The Blackloists were among the first to use natural philosophy in this way but they were by no means unique. Descartes and Hobbes came to be seen in much the same light, as did Spinoza. At the very end of the century, as Margaret Jacob has shown, John Toland also tried to use his version of the
mechanical philosophy to promote his Republican ideology.\textsuperscript{8}

The fact that such religious and political extremes could all use the mechanical philosophy to promote their ideological positions ensured that the only safe response was not to fight fire with fire, as James and Margaret Jacob and others have claimed, but was rather to adopt a cautious sceptical stance and an avowed disinterest in such controversial matters as politics and religion.\textsuperscript{9}

The evidence presented in this thesis should also help us to remove one of the pillars of recent socio-political interpretations or 'reconstructions' of the development of early modern science which are completely misleading. The dead, inert matter which has been (wrongly) attributed to mechanists like Boyle and Newton has been seen as a means of providing a metaphysical basis for the Whig constitution of 'commercial capitalism' and even for a movement to subjugate women.\textsuperscript{10} However, if we look in detail at the matter theories of thinkers like Boyle, Hooke, Power, and Newton we can find many similarities with the matter theories of more 'subversive' thinkers like Digby, Hobbes and Toland.\textsuperscript{11} The dichotomy between inert passive matter and self-moving matter, which the Jacobs relate directly to the dichotomy between conservative constitutional Monarchists and radical Republicans, simply does not exist.\textsuperscript{12}

The politically conservative natural philosophers did
not formulate a completely different matter theory to oppose the ideologies of political extremists; they simply developed a sceptical methodology which could be used to deny any dogmatic pronouncements in natural philosophy. The fact that the scientific ideas of Boyle and Newton have played a much greater role in the development of modern science than those of Digby, Hobbes or Toland cannot be attributed to the political views of Boyle and Newton. Rather it would seem that Boyle and Newton were successful because their methodology enabled them to keep science and ideology as separate as possible. In other words, I have been suggesting in this thesis that the scientific endeavour to understand the workings of the Universe succeeds best when it can dissociate itself from the transient and parochial debates of contemporary local politics. This was no less true in the beginnings of modern science in the seventeenth century as it is today.

The final conclusion I wish to draw is that the principles of the Hellenistic and medieval tradition of light metaphysics provided a virtually ubiquitous influence on the mechanical philosophy. Light was frequently invoked as a self-moving material principle which could give rise to motions or even qualitative changes in bodies. I do not wish to imply that these ideas were passed on from one mechanist to another. Hooke's ideas about light as an active principle, for example, need not have been derived from a reading of Hobbes' early manuscripts. Such direct influences would be
impossible to establish and, in any case, need not be assumed. It seems safe to conclude that such ideas merely testify to a set of common assumptions about the nature and role of light which were shared by most seventeenth-century naturalists. The role of light metaphysics in the development of modern science has already been demonstrated by A. C. Crombie in his classic study of Robert Grosseteste. Dr Crombie's work concentrated on the role of light metaphysics in the development of the experimental method and the mathematical analysis of natural phenomena. I hope that my own perspective, concentrating on the more metaphysical aspects of the tradition can be seen as a complement to his analysis. The Scientific Revolution which saw the establishment of the experimental method, the methods of mathematical analysis, and the attempt to explain all natural phenomena in terms of matter in motion may well be said to owe more to the tradition of light metaphysics than to any other single factor. The rise of modern science, therefore, should be attributed not to the rise of capitalism or the tension between 'cosmic Toryism' and 'mundane Whiggism' but rather to a reassessment of an age-old tradition which embraced concepts of metaphysics, cosmology, aetiology and methodology.
NOTES TO INTRODUCTION


3. M.B. Hall, op. cit., (2), 509-10. See also Chapter 7 above.


15. On this aspect of Leibniz's philosophy see H. Pagel, 'The religious and philosophical aspects of Van Helmont's science and medicine', Supplement to the Bulletin of the history of medicine, 2, (Baltimore, 1944), p. 33.

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4. Even the sympathetic Charleton referred to Epicurus in an early work as the 'Secretary of Hell', see Walter Charleton, The Darkness of atheism dispelled by the light of nature. A physico-theological treatise, (London, 1652), 158. Epicureans were condemned in the eyes of Christians by the unwarranted
identification of their views with the Biblical epigram, 'let us eat and drink; for tomorrow we die,' I Corinthians, XV, 32. Epicurus was branded as an atheist by the early Church Father, Lactantius, De ira dei, IX, in Patrologia Latina, VI.

5. Diogenes Laertius, Lives of the philosophers, includes three letters which were allegedly written by Epicurus himself. See Cyril Bailey, The Greek atomists and Epicurus, (Oxford, 1928).


8. Most obviously Gassendi denies the eternity of the world and insists that the atoms were set in motion by God at the creation. P. Gassendi, Syntagma philosophicum, pars secunda quae est physica, sectio prima, liber I, cap 6 and liber IV, cap 2 and 5, in Opera omnia, 6 vols. (Lyon, 1658), I, 162-70, 287-95 and 311-19.


13. The dispute between monistic and pluralistic cosmogonies is extremely difficult for the modern mind to grasp. There are, however, a number of excellent guides through this topic. See, for example, Kirk and Raven, op. cit., (10), 263-306; and Georgio de Santillana, The origins of scientific thought from Anaximander to Proclus, 600 B.C. - 500 A.D., (New York, 1961), 88-106. On Zeno of Elea see Kirk and Raven, op. cit., (10), 286-97; and the article by Gregory Vlastos on Zeno in The Encyclopaedia of philosophy, 8 vols. (New York and London, 1967), VIII, 376-7.


18. Ibid., 212a5-6.

19. There are a number of useful studies of the subsequent history of Aristotle's arguments about the void. See, for example, A.Koyré, 'Le vide et l'espace infini au XIVe siècle', Archives d'histoire doctrinale et litteraire du moyen-age, 24, (1949), 45-91; and E. Grant, Much ado about nothing: theories of space and vacuum from the Middle Ages to the Scientific Revolution, (Cambridge, 1981).


25. *Ibid.*, 216a24-7. For a further discussion of these arguments see D.J.Furley, 'Aristotle and the atomists on motion in a void', in P.K.Machamer and R.G. Turnbull, (eds.), *Motion and time, space and matter: interrelations in the history of philosophy and science*, (Columbus, Ohio, 1976), 83-100.


28. Ibid., 28, (67), 39, (77).

29. Ibid., 15, (54).

30. British Library, Add. MS. 6782b, f.369r (There is a copy at Harley MS. 6002, f. 9v).


32. Galileo himself suggests that his ideas are not entirely convincing, *op. cit.*, (27), 35, (73).

33. This problem (somewhat differently formulated) is to be found in the Pseudo-Aristotelian *Mechanical problems*. See Aristotle, *Minor works*, trans. by W.S. Hett, (London, 1963), 343-7. For a discussion of Galileo's treatment of this problem and its relevance to another aspect of the attempt to revive atomist theories see A.G.Molland, 'The atomisation of motion: a facet of the scientific revolution', *Studies in the history and philosophy of science*, 13, (1982), 31-54. For a slightly later attempt to use Aristotle's wheel in the plenist-vacuist debate see Franciscus Linus, *Tractatus de corporum inseparabilitate*, (London, 1661), and Robert Boyle, *A defence of the doctrine touching the spring and weight of the air ... against the objections of Franciscus Linus ...*, (Oxford, 1662), in Boyle,

35. Galileo's essential agreement with Aristotle here has been forcefully argued in A. Mark Smith, 'Galileo's theory of indivisibles: revolution or compromise?', *Journal of the history of ideas*, 27 (1976), 571-88.


40. Patrizi, *op cit.*, (38), f.67v. For a similar argument in Bruno see Michel, *op. cit.*, (39), 133.

41. Patrizi, *op. cit.*, (38), f.67v.

42. Lasswitz, *op. cit.*, (1), I, 399.


46. Ibid.

47. Michel, *op. cit.*, (39), 146.

48. Circles, for example, can only be composed of one spherical atom or seven (six contiguous around the central one), or nineteen (twelve contiguous about six, around one) and so on. The mind makes these configurations into circles, but the true configuration is imperceptible to the senses. See *Opera* (note 39), I, pt. 3, 189-90. Bruno's breathtaking arrogance here should be compared with Harriot's considerations about the atomic structure of a circle. In a circle whose centre is $a$, Harriot asks, 'what will be the number of atomi that are successively about the point $a$? Infinite they must needs be or els infinite lines could not be supposed actualie from the point $a$ to the peripherie, and infinite also are they in the peripherie. But now I demand whether they are equally infinite or not. If about the centre are less infinite then there cannot from the centre $a$ to every point in the peripherie be understood a right line, but wee must understand those atomi about the centre that were supposed indivisible divisible, which were absurd ...', British Library, Harley MS. 6002, f.9.

49. Bruno, *Opera*, (note 39), I, pt. 3, 228-9. Bruno refers to this square array as the 'Campus Democriti'.

50. As far as I can gather Bruno does not consider the significance of the gaps between the spheres in this particular array, but for a general exposition of such 'voids' see Michel, *op. cit.*, (39), 146-7.

51. It seems to me that Patrizi and especially Bruno are not only deviating from sound mathematics but even from the norms of rationality in general. As Michel wearily puts it, Bruno 'refers so often to logical impossibilities that it would be tedious to stress the matter'. Michel, *op. cit.*, (39), 133. Similarly, Atanasijevic declares that Bruno 'loses his way whenever a logical or mathematical deduction is necessary', *op. cit.*, (39), 94. I must acknowledge a debt to both Michel and Atanasijevic whose heroic efforts have helped me to find my way through Bruno's *De minimo*. With their help I have written a fuller consideration of Bruno's atomism and its possible influence on Harriot which
I have drawn on heavily for this section of the chapter. See John Henry, 'Thomas Harriot and atomism: a reappraisal', History of Science, 20, (1982), 267-296.

52. On Galileo's compromise see A. Mark Smith, op. cit., (35), on Harriot's ultimate failure to revive a coherent atomist philosophy see Henry, op. cit., (51).

53. It is used loosely by Sir Kenelm Digby, for example, in his Two treatises. In the one of which the nature of bodies: in the other the nature of mans soule is looked into: in way of the discovery of the immortality of reasonable soules, (Paris, 1644); and by Henry Power, Experimental philosophy, in three books: containing new experiments, microscopical, mercurial, magnetical. With some deductions and probable hypotheses, raised from them in avouchment and illustration of the now famous atomical hypothesis, (London, 1664). There are many further examples.

54. The concept of the natural minimum - the smallest particle of a body which takes part in physical or chemical change - was a very significant feature of medieval Aristotelian exegesis and played a crucial role in shaping the matter theory of the mechanical philosophy. The importance of the minima naturalia tradition has not yet been adequately recognised. The only valuable sources are the two pioneers in the field: Andrew G. van Melsen, op. cit., (1), 30-48, 58-78; and V. P. Zubov, 'Zur Geschichte des Kampfes zwischen dem Atomismus und dem Aristotelismus im 17 Jahrhundert (minima naturalia und mixtio)', in G. Harig (ed.), Sowjetische Beiträge zur Geschichte der Naturwissenschaft, (Berlin, 1960), 161-91. But see also E.J. Dijksterhuis, The mechanization of the world picture, trans. by C. Dikshoorn, (Oxford, 1961), 200-9, 277-9.


56. These anti-Aristotelian theories of motion are often traced back to John Philoponus (c. 575) whose commentary on Aristotle's Physics was reprinted seven times between 1539 and 1581. See C.B. Schmitt, 'A fresh look at mechanics in 16th-century Italy', History and philosophy of science, 1, (1970), 161-75; and M. Clagett, The science of mechanics in the Middle Ages, (Madison, Wis., 1959), 509-12. See also Edward Grant, 'Motion in the void and the
principle of inertia in the Middle Ages', Isis, 55, (1964), 265-92; and idem, Much ado about nothing, (note 19), 24-66.

57. For one of the most famous of these Digressiones see Aristotelis physicorum libri quatuor, cum Ioannis Grammatici cognomento Philoponi commentariis, quos nuper ad graecorum codicum fidem ... restituit Ioannes Baptistae Rasarius etc., (Venice, 1581), 202-8.

58. Grant, Much ado about nothing, (note 19), 103-258.

59. Ibid., 221-58; and Alexandre Koyré, From the closed world to the infinite universe, (Baltimore, 1957), 125-272.


64. Ibid., 105. On the notion of 'imaginary' space in scholastic thought see Grant, op. cit., (19), 116-21, 174-81.
Boyle, Works, (note 33), III, 372. For an excellent discussion of the role of pneumatical experiments in the debates about the possibility of vacuum see Cornelis de Waard, L'expérience barometrique - ses antecedents et ses explications, (Thouars, 1936).

See above p. 10.

Digby, op. cit., (53), 20-1. Galileo estimated that water is 400 times heavier than air and Marinus Ghetaldus that gold is 19 times heavier than water. See Galileo Galilei, Two new sciences, (note 27), 80; and Marinus Ghetaldus, Promotus Archimedis seu variis corporum generibus gravitate et magnitudine comparatus, (Rome, 1603), p. 32.

This is a standard atomist assumption, of course. Digby extends the argument to point out that the spaces between the particles of the rarefied body cannot be filled with another substance. For, if that substance is continuous it would be as dense as the body it is interspersed with, and rarefaction would not be detected. If it is argued that the interparticulate substance is rarer it must be so by virtue of voids between its particles or an infinite regress ensues. The real alternative, Digby claims, is the Aristotelian definition of rarity: more quantity (volume) for less substance, op. cit., (53) 18-19.

Digby, op. cit., (53), 21.

See Chapter 7 for a discussion of Newton's matter theory and further bibliography.

It should not be forgotten that Aristotle too rejected the concept of action at a distance.

On Henry More see Chapter 5. On Newton see Chapter 7.


University Library, Cambridge, Add. MS. 3970, f.620r. This has been commented upon by J.E. McGuire, 'Force, active principles and Newton's invisible realm', Ambix, 15, (1968), 154-208, p. 171; and Alan Gabbey, 'Force and inertia in seventeenth-century dynamics',
75. As will be seen (in Chapter 4), I have to exclude the mature philosophy of Thomas Hobbes from this generalisation. Nevertheless, my comment is applicable to the early pre-1655 philosophy of Hobbes. See Chapter 2.

76. John Toland, Letters to Serena, (London, 1704), 164. I have chosen to compare Power with Toland quite deliberately. Partly because Toland is so explicit in his beliefs about active matter. But also because it has recently been argued that Toland's matter theory derived from his radical political stance: see M.C. Jacob, 'John Toland and the Newtonian ideology', Journal of the Warburg and Courtauld Institutes, 32, (1969), 307-31; and idem, The Newtonians and the English Revolution, 1689-1720, (Hassocks, 1976), 201-50. By comparing Toland with Power I hope it will become clear that, contrary to Jacob's suggested implications, it cannot be concluded that scientific ideas are merely epiphenomena of political endeavours. The fact that theories of innate activity in matter can be found in many politically diverse thinkers from the 1630s through to the eighteenth century (as I hope to show in this thesis) suggests rather that such scientific ideas have a certain autonomy and are dictated by the requirements of natural philosophy rather than politics. The fact that a particular individual's philosophical ideas may be linked by him to his own political beliefs is not in the least surprising - indeed it is rather trivial: everybody likes to imagine they are thoroughly consistent in all their beliefs.

77. Power, op. cit., (53), Preface, sig. b4r.

78. Toland, op. cit., (76), 167; Power, op. cit., (53), sig. b3v.

79. This is the title of Toland's 'Letter' on matter theory, op. cit., (76), 163-239.

80. Power, op. cit., (53), sig. c2r.

81. Ibid., sig. c1v-c2r.

82. For biographical details on Hobbes, see Dictionary of national biography.
NOTES FOR CHAPTER 2

1. British Library, Harley MS. 6796, ff. 297-308. This has now been published as an appendix in Thomas Hobbes, The elements of law, natural and politic, ed. by F. Tünnies, (London, 1889), 193-210. I will refer to this edition throughout and cite it simply as Little treatise.


3. Ibid., Brandt considers the possible sources on The little treatise, pp. 55-84.

4. Ibid., 102. See also 285, 287, 367-8.

5. Little treatise, 197, also 193, 195.


9. Discussed and quoted in Brandt, op. cit., (2), 52-3. Furthermore, as we shall see later (below, p. 37 and note 22) in a letter of August 1635 Hobbes implied that he had not yet written The little treatise.


11. Ibid., 55-84.


15. For an excellent survey of this kind of reaction to Hobbes see S.I. Mintz, The hunting of Leviathan.


18. There is now a sub-industry in the history of science devoted to the study of Thomas Harriot. For a bibliography see J.W. Shirley, (ed.), Thomas Harriot, Renaissance scientist, (Oxford, 1974), 169-74. Robert Hues has succeeded in eluding all but passing scholarly attention. Warner falls between these two extremes but there is plenty of scope for more research. In the meantime see J. Jacquot, 'Harriot, Hill, Warner and the new philosophy' in Shirley, op. cit., 107-28.


20. It is well known that Warner and some of his friends believed that William Harvey (1578-1657) plagiarised the idea of blood circulation from Harvey. However, these allegations have failed to attract scholarly attention. There are brief treatments in Jacquot, op. cit., (18), 120-3; Charles Webster, 'Harvey's conception of the heart as a pump', Bulletin of the history of medicine, 32, (1965), 508-17, p. 516; and H.P. Bayon, 'Allusions to a "circulation" of the blood in manuscripts anterior to De motu cordis, 1628', Proceedings of the Royal Society of Medicine, 22, (1938/9), 707-18.

22. Letter dated August 25, 1635. Quoted from Jacquot, op. cit., (18), 124; Jacquot, op. cit., (7), claims that Mersenne published optical treatises by the two men in his Universae geometriae mixtae mathematicae synopsis ..., (Paris, 1644), p. 20. Jacquot believes books VI and VII to be by Warner and Hobbes respectively. However, book VI seems to be by Hobbes and there is no indication of Warner's authorship anywhere in the collection. I believe Jacquot is relying on Wood, op. cit., (17), II, 302, who makes the same error. Even so, Warner may have written one of the tracts in Mersenne's compendium.

23. Little treatise, 198.


25. Little treatise, 205. Principle 9, Section 1 reads: 'Whatsoever moveth another, moveth it either by active power inherent in itself, or by motion received from another', p. 193.

26. Ibid., 195.

27. It is clear that Hobbes is here referring to local movement. He is not considering movements such as heart-beat.


29. Little treatise, 205-6.

30. B.L. Additional MS. 4395, f. 2r.

31. Ibid.

32. Little treatise, 209-10.

33. Warner's discussion is much more discursive than Hobbes'. Some sensations will affect the animal cum dolore, he says, 'that is to say with a kind of violent or contra-natural torsion or distraction of the spirits'. While other sensations will be cum indolentia seu absque dolore, 'that is to say with the reduction or reversion of the spirits to their natural state which in comparison of their immediately precedent distraction may appeare to be a degree of volupty'. Accordingly 'by the
sensation or rather fantasiation of this difference we come to fantasiate the one sub forma seu specie mali and the other sub forma seu specie boni....'. B.L., Add. MS. 4395, f. 33v-33r (reading retrograde). Interestingly this view of happiness as lack of pain shows Epicurean influence. See, Walter Charleton, (ed.), Epicurus's morals, (London, 1656), p. 1 sqq. For Hobbes' discussion see Little treatise, 208-9.

34. Little treatise, 206-7; B.L., Add. MS. 4395, f. 28r-v.
35. B.L., Add. MS. 4395, f. 28v; cf. Little treatise, 207.
36. Little treatise, 208.
37. B.L., Add. MS. 4395, f. 30r-31r.
38. Little treatise, 207.
40. See note 22 above.
41. B.L., Add. MS. 4394, f. 396r; Thomas Hobbes, English works, (note 8), I, 188.
43. Vindiciae academiarum (note 16), 7. In spite of the close similarities between Warner's ideas and those of Hobbes it is still not possible to insist that Hobbes was merely a plagiarist. There is no indication in the records that Warner ever accused Hobbes of plagiarism and yet he did accuse Harvey (see note 20 above). It is conceivable that there was a collaboration between the two men but again there is no hint of this in surviving correspondence etc. Indeed, in view of the impossibility of accurate dating it is possible that Warner copied Hobbes. However, this seems highly unlikely. If Warner's charge against Harvey was to have any force he must have been known to have written at least part of the British Library collection of his papers
before 1628. Furthermore some materials by Warner, including what looks like a brief summary of the theories detailed in the British Library collection appear in the collection of Nathaniel Torporley's papers at Syon House; Sion College, MS. ARC. L40.2/E 10). This material must predate Torporley's death in 1632. If the Little treatise was composed between 1634 and 1636 as seems likely (see above notes 9 and 22), then Warner could hardly have plagiarised Hobbes. Furthermore, Warner's papers are much richer in details and in arguments than Hobbes' deliberately spare 'Euclidean' discussion and so could hardly have been stolen from Hobbes. It may well be, therefore, that Warner has been cheated of some deserved recognition as the first English mechanical philosopher (see below note 106) by Hobbes. We shall probably never know.


45. Out of a total of forty-five works on the list, four are by Grosseteste - if we include the Summa totius philosophiae, of the pseudo-Grosseteste - and twenty three are by Bacon. Also included are 'Hermes de 6 rerum principj', 'Procli de malorum subsistentia', 'Platonis Parmenides in commento Procli' and other neo-Platonic writings. Pacchi, op. cit., (44), 500-1.


48. Little treatise, 197.


50. Certainly Hobbes would wish to avoid the use of the
word 'atom' with its many untenable associations for his readers, see above, Chapter 1, pp. 11-21.

51. See above p. 32 and Brandt, op. cit., (2), 102.

52. Little treatise, 195. It is this conclusion which Hobbes invokes later when he argues that 'animal spirits' cannot have inherent power because an animal may sometimes remain at rest. See above p. 38.

53. Little treatise, 197.

54. Ibid., 199.

55. B.L., Add. MS. 4395, f. 129r.

56. B.L., Add. MS. 4394, f. 400r.

57. Ibid., f. 400r-v. Warner suggests that space can be said to exist through time but time cannot be said to exist in space: 'it is certain that they [space and time] are in respect of being more prime than materia and vis though not tempore yet natura, and time more prime than space because time is applicable to space by way of predications and not e contra'.


59. B.L., Add. MS. 4394, f. 204v.

60. See Sarah Hutton, op. cit., (58), 346-7; and Aristotle, Physics, 219b3-4, 223a15-30, 223b10-12 and elsewhere.

61. Plato, Timaeus, 49A. The best edition is F. M. Cornford, Plato's cosmology, the Timaeus of Plato translated with a running commentary, (London, 1937), see p. 177. There can be no doubt that Warner did believe time and space to have a real absolute existence. Consider B.L., Add. MS. 4394, f. 203v: 'The being of time or space cannot be proved a priori or directly but only a posteriori or indirectly by deduction ad impossible, drawing the non-existence of them to a contradiction of the sense or phenomena unless it may be counted a sufficient
proofe a priore of the being or existence of a thing, that the mynde cannot imagine it not to be, as to him that so doth conceive it doutes it is, for to prove a thing to be, is nothing but to cause the mynde that is ignorant or doutful thereof to conceive or apprehend it as a thing really being. That is to say, to know or be assured that onto the intellectual concept or phantasme there is a thing without the fantasy really existing answerable to that intellectual concept and congruent thereto. Moreover the essence or quiddity thereof cannot be conceived but the reality and existence must necessarily be also conceived, so that it is impossible for a man to dout of the existence of time or space understanding only what is meant by those names, but that he must needes contradict his own conscience. A posteriore it will safely be proved for unles there be time and space there is nothing, for in affirming a thing to be we affirm it only to possesse some space distinct from all other things and be possessed of some time concurrent with all other things'. Warner's thinking here may be directly compared with that undisputed neo-Platonist thinker, Henry More: 'extension is a real attribute of a real subject (namely matter) which is independent of our imagination. Indeed, we are unable not to conceive that a certain immobile extension pervading everything in infinity has always existed and will exist in all eternity (whether we think about it or do not think about it)', Enchiridion metaphysicum, (London, 1671), 167. Elsewhere More reiterates that extension 'is so imaginary that it cannot be dis-imagined by human understanding', Divine dialogues, 2 vols., (London, 1668), I, 104. This aspect of More's arguments about space has been seen as an anticipation of Immanuel Kant's arguments in the Transcendental aesthetic; see J.T. Baker, An historical and critical examination of English space and time theories from Henry More to Bishop Berkeley, (Bronxville, New York, 1930), 10. The fact that Warner himself anticipated More is testimony to the power and sophistication of Warner's philosophical acumen.

63. B.L. Add. MS. 4394, f. 129r.

64. Ibid., f. 212r.

65. See also ibid., f. 204v where Warner tells us that 'space is corporeally or spherically infinite'. I have already pointed out in Chapter 1 that dimensionality or extension was regarded as a sufficient definition for corporeality in Aristotelian thought and that this view prevailed well into the seventeenth century. See above, pp. 8-9, 23.

66. All but two of the examples of the usage of δύνατόντας cited in G.W.H. Lampe, A Patristic Greek lexicon, (Oxford, 1961-8) and Liddell and Scott's Classical Greek dictionary, revised by H.S. Jones and R. McKenzie, (Oxford, 1968), are taken from neo-Platonic sources. The two exceptions are the Epicurean, Philodemus, who is most unlikely to have been known to Warner, and Sextus Empiricus. The (essentially) neo-Platonic distinction between corporeal and incorporeal in terms of resistance rather than extension can be clearly seen in Iamblichus, De vita Pythagorica, (Amsterdam, 1707): 'Mathematical speculation and theories are about those things that mediate between corporeal and incorporeal entities and are on the common border of both (for they possess three dimensions like bodies but lack resistance like incorporeal things)'. Quoted in E.E. Maechling, 'Light metaphysics in the natural philosophy of Francesco Patrizi da Cherso', (M. Phil. thesis, University of London, 1977), 25. The idea of 'border-line' entities which are extended but incorporeal is an important facet of neo-Platonic thought and is to be found in Plotinus. See A.H. Armstrong, The architecture of the intelligible universe in the philosophy of Plotinus: an analytical and historical study, (Cambridge, 1940), 55-7. See also B. Brickman, An introduction to Francesco Patrizi's 'Nova de universis philosophia', (New York, 1941), 33, 59-60; and J. Henry, 'Francesco Patrizi and the concept of space: his contribution to the development of the concept of void space and the infinite universe', (M. Phil. thesis, University of Leeds, 1977), 104-7.

67. B.L., Add. MS. 4394, F. 387r.

68. Ibid.

69. Ibid., f. 389r.

70. Ibid., f. 389v.

71. Ibid., f. 129v, 386r, 212r.
In many ways it is misleading to call this a tradition of light metaphysics since, as David Lindberg has pointed out, the tradition goes far beyond metaphysics and into the realms of physics and other aspects of natural philosophy. See Lindberg, op. cit., (46), p. 96. Nevertheless, I will continue to refer to it by its familiar name. For a summary of the main tenets of 'light metaphysics' see the extract 'concerning lux and its properties' from Bartholomew the Englishman (fl. 1220-1250), Concerning the properties of things, translated by B.S. Eastwood in E. Grant, (ed.), Source book in medieval science, (Cambridge, Mass., 1974), 383-4. On its beginnings see Armstrong, op. cit., (66), 52-7. See also C. Baemker, Witelo, ein Philosoph und Naturforscher des XIII. Jahrhunderts, (Munster, 1908), 357-67; E.E. Maechling, op. cit., (66); and the works cited in note 95 below.

On this see the references in Crombie, op. cit., (49), 57n, 73, 105, 109n, 128-9, 132n. The analogy between God and light is still fairly pervasive in theological literature. For a seventeenth-century example consider Nathaniel Culverwell, An elegant and learned discourse of the light of nature, with several other treatises, (London, 1652), this also includes his Spiritual optics.

The Liber de causis or De expositione bonitatis pure is an Arabic compilation of extracts from Proclus' Elements of theology. See Grant, op. cit., (73), 37. It was falsely attributed to Aristotle.

These are perhaps best illustrated by the speculations of Robert Grosseteste which are quoted and discussed below pp. 55-57. See also the theory of Proclus recorded in Simplicius, In Aristotelis physicorum libros quattuor priores commentaria, ed. by H. Diels, (Berlin, 1882), 612 and discussed in P. Duhem, Le système du monde, 7 vols., (Paris, 1913-56), I, 359.

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79. On knowledge of Patrizi's works in England see Henry, op. cit., (73), 138-9, 143-50, 156-63. Warner is known to have fetched books from Henry Percy's library to the Tower of London during Percy's imprisonment. A list of these books survives and works by Patrizi are included. See Edward de Fonblanque, Annals of the House of Percy from the conquest to the opening of the nineteenth century, 2 vols., (London, 1887), II, 626-30.

80. Francesco Patrizi, Nova de universis philosophia. In qua aristotelica methodo, non per motum, sed per lucem, & lumina, ad primum causam ascenditur ..., (Ferrara, 1591 and Venice, 1593).

81. B.L., Add. MS. 4394, f. 204v, and Patrizi, op. cit., (80), 61r.

82. B.L., Add. MS. 4394, f. 400r, and Patrizi, op. cit., (80), 61r.

83. B.L., Add. MS. 4394, f. 384v, and Patrizi, op. cit., (80), 61r.

84. B.L., Add. MS. 4394, f. 204v, and Patrizi, op. cit., (80), 62v.

85. See above p. 49 and B.L., Add. MS. 4394, f. 212r.

86. Ibid., f. 204v.

87. Patrizi, op. cit., (80), 65r, 68r. See also note 66 above.

88. Patrizi, op. cit., (80), f. 62v: 'It is antitypia which they also call anteresis which is proper to a body, in so far as it is a natural body. This is resistance'. Cf. B.L., Add. MS. 4394, f. 212r, quoted above at p. 48 and note 66 above.

89. Valori was the librarian at the Laurenziana Library in Florence.

90. Francesco Patrizi, Lettere ed opuscoli inediti, ed. by D.A. Barbagli, (Florence, 1975), 70. See also the extended title of Nova philosophia, note 80 above.
91. Above p. 50. See B.L., Add. MS. 4394, f. 389r and f. 389v.


93. R.H. Kargon, op. cit., (19), p. 36 prefers to see Warner as an 'ardent atomist'. The details of Warner's matter theory are complex and difficult to fathom. I hope to deal with this in a separate article. In the meantime it may serve as an indication of the inadequacy of Kargon's account to compare Kargon's view that 'In Warner's atomism we can discern subtle changes away from the atomism of Epicurus' Letter to Herodotus ...', (p. 39) with Warner's own unequivocal axiom: 'Divisibility a property of matter', B.L., Add. MS. 4394, f. 386r. Equally unequivocally, I believe, and thoroughly redolent of light metaphysics, Warner redeclares on the same page: 'Matter and virtue radiative fill the universall space'.

94. See above notes 44 and 47.

95. See Baeumker, op. cit., (73), 392 sqq; L. Baur, 'Das Licht in der Naturphilosophie des Robert Grosseteste', in Festschrift Georg von Hertling, (Freiburg, 1913), 42-55; and Crombie, op. cit., (49), especially 104-10 and 128-31. I have drawn heavily upon Crombie's book which does not confine itself to a study of Grosseteste but shows the wider influence of his ideas on subsequent methodology. See also Lindberg, op. cit., (49), especially 94-102 and 107-19.

96. I believe that there are hints of an emanationist cosmogony in Warner's writings although it is by no means explicit. He vigorously denies the possibility of creation ex nihilo but his grounds for doing so are rather unusual: 'Nothing can not be the cause of anything. Nor some thing or any thing be said to be the cause of nothing. Therefore ex nihilo nihil fit; true whether there be an efficient potential and no matter or a matter capable of forme and no efficient actuall etc.'.

Sion College MS., ARC. L40.2/E10., f. 82r, (copy at f. 88r). This seems reminiscent of Patrizi's denial that God could create the world out of nothing for 'Nemo dat quod non habet'. Although God may create the world when there is no primary matter he does not create from nothing because He Himself exists and creates the world out of himself.
by emanation. Crucial for this concept of creation is the belief that a light source may emit light \textit{without diminishing itself}. God can, therefore, create the world out of himself by emanation without diminishing Himself (Patrizi, \textit{op. cit.}, (80), 'Panarchia', Book I, f. 1r; see also Brickman, \textit{op. cit.}, (66), 57-8). Patrizi links his emanationist metaphysics with the doctrine of the Trinity which he identifies with the supernal world of neo-Platonic thought. Surprisingly, Walter Warner's mentor Thomas Harriot has left in his manuscripts a suggestion that he too believed that nothing could come from nothing but that everything could come from the Trinity (B.L., Add. MS. 6788, f. 493r):

\begin{align*}
\text{ex} & \\
\text{nihilo nihil fit} & \\
\text{uno nihil aliud} & \\
\text{duobus nihil tertium} & \\
\text{Tribus quod libet}
\end{align*}

97. The quotation is from Grosseteste's \textit{On light}. This is now published as R. Grosseteste, \textit{On light}, trans. by C.C. Reidi, (Milwaukee, 1942), but I have quoted it from Crombie, \textit{op. cit.}, (49), 106. Crombie glosses the curious statement that 'matter is a substance ... lacking all dimensions' in this way: 'i.e. body as such, \textit{simpliciter}, is a punctual, positional substance lacking dimensionality'.

98. Crombie, \textit{op. cit.}, (49), 107. This extract is from Grosseteste's \textit{De motu corporali et luce}.

99. See above p. 50 and Sion College MS. ARC. L40.2/E10, f. 88v.

100. Crombie, \textit{op. cit.}, (49), 107.


102. See note 46 above. On the influence of De \textit{radiis stellarum} on the conception of 'species' and their multiplication see Vescovini, \textit{op. cit.}, (46), 40; Thorndike, \textit{op. cit.}, (46), 646; and Lindberg, \textit{op. cit.}, (46), 97-8.

103. I have quoted this from Lindberg, \textit{op. cit.}, (46), 19. See also Vescovini, \textit{op. cit.}, (46), 46.

104. See note 49 above.

105. See note 44 above. \textit{De speculis} of Jordanus Nemorarius also appears on the list and John of Dumbleton's \textit{De luce}. 

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106. It must remain a moot point as to whether this blend is original with Hobbes. After all the first advocate of this hybrid philosophy may well be Walter Warner. I have concentrated here on Warner's light metaphysics but there are a number of suggestions that his work is strongly mechanistic. As Jacquot has pointed out, Warner explicitly formulated the principle of rectilinear inertia a long time before Hobbes did so (and possibly even before Descartes). See Jacquot, op. cit., (18), 119. It is worth remembering also that when Hobbes did describe the principle he completely failed to grasp its significance. See Brandt, op. cit., (2), 327-9. Furthermore, a contemporary record tells us that Warner used to say that Harvey missed the main point in his study of the heart because he never realised, as Warner did, that the heart was simply 'a perfect hydraulic'. See Jacquot, op. cit., (18), 120. If this report is true it suggests that Warner was far more of a mechanist than Hobbes, who seems to have accepted Harvey's vitalistic view. See Chapter 4 below.


113. See Bartholomew the Englishman, 'Concerning *lux* and its properties', op. cit., (73), 383; and Brickman, op. cit., (66), 28.

114. *Little treatise*, 203-4. Hobbes refines the original distinction in this way because he wishes to reiterate the material nature of light (discussed here immediately below). The argument runs: 'Primitive light and colour etc. are Accidents; much more so is Derivative light (by Primitive light is understood *Lux*, by derivative, *Lumen*), and seeing derivative light and colour are not inherent in the Medium (by the 2 Concl. Sect. 2) their utmost subject must be the species; and consequently those species must be substance (by the 3 Concl. Sect. 1').

115. Clearly, Hobbes' mechanical philosophy relies upon a corpuscular concept of matter as all mechanist philosophical systems do. For a discussion of the
similarities between Hobbes' conceptions in The little treatise and ancient atomism see Brandt, op. cit., (2), 73-7.

116. See Crombie, op. cit., (49), 99, 113-5, 145-8; and Little treatise, 200. There do seem to have been some indications in Grosseteste's writings that light is a body, however. See Crombie, op. cit., 109n, where he tells us that 'both lux and lumen were bodies (corpora); and Bartholomew the Englishman (note 73) tells us that St. Augustine held light to be 'a corporeal being' (p. 383). See also note 121 below.

117. The prevailing view was, of course, Aristotelian. See Aristotle, De anima, II, 7. For a brief account see A.I. Sabra, Theories of light from Descartes to Newton, (London, 1967), 46-8. This should be supplemented with David C. Lindberg, 'Medieval Latin theories of the speed of light', in Roemer et la vitesse de la lumière, (Paris, 1978), 45-72.

118. Little treatise, 200-2.


120. Brandt, op. cit., (2), 102.

121. It rather looks as though this materialistic conception of light and other species is unique to Hobbes. Certainly Warner held his vis or 'virtue radiative' to be incorporeal - see, for example, Sion College MS. ARC. L40.2/E10, f. 83v. However, as I have already hinted, there are indications in Grosseteste's writings that light might be considered a body; see note 116 above. Furthermore, although light itself is an 'incorporeal corporeal' for Patrizi it can 'thicken', as it were, to become heat, fire and eventually fluor - his principle of matter. Light is not only the efficient and formal cause for Patrizi, as it is for Grosseteste, but is often the material cause also. See Brickman, op. cit., (66), 61; and Maechling, op. cit., (73), 54-6. It is quite likely that Hobbes was familiar with Patrizi's work. Some-time in the early 1630s Hobbes drew up a list of books for an 'ideal library'. This list includes a number of works by Patrizi: Della nuova geometria, (Ferrara, 1587), Nova de universis philosophia, (Venice, 1593), and Patrizi's translation of Proclus, Elementa theologica et physica, (Ferrara, 1583). See A. Pacchi, 'Una "Biblioteca ideale" di Thomas Hobbes: il MS. E2 dell'archivio di Chatsworth', ACME: Annali della
See p. 58 above. It is impossible to say what it might be that does not give off species of some kind - most bodies are visible after all.

The sun is invoked as an agent in The little treatise, at p. 198, 201. See also Chapter 4 below. Descartes, of course, explains the brilliance and heat of the sun in terms of the rapid churning motion and friction of the corpuscles at the centre of vortexes. See R. Descartes, Le monde, ou traité de la lumière, translated by M.S. Mahoney (New York, 1979), chapter 8, pp. 84-7.

'Experience' is invoked by Hobbes in The little treatise, pp. 198, 199, 202, 205, 206, 207.

Actually Hobbes' reasoning takes an invalid step here. The '2 Concl. Sect. 2' reads: 'Agents at distance worke not all on the Patient, by successive action on the parts of the Medium' (p. 198). Hobbes is now assuming that since 'not all' agents work this way none do. This is not necessarily so.

Magnetism was one of the major difficulties confronting the mechanical philosophy. See Chapter 6, section 4 below.

If something like steel continually gives off species then it is difficult to imagine what does not emit species. If all bodies do emit species and species are material corpuscles, it is surely reasonable to assume that the species are tiny exemplars of the body from which they are emitted. Effectively, then, all kinds of matter have innate activity. See also note 122 above.

See above, Chapter 1, pp. 28 or intro. p. IX.

Crombie, op. cit., (49).

Crombie, op. cit., (49), 90-127, especially 104-15; 128-134; and passim.

I am actually quoting Bartholomew the Englishman, reporting the words of St. Augustine, in Grant (ed.), Source book in medieval science, (note 73), 385.

136. See Chapter 4 below.

137. Thomas Hobbes, The elements of philosophy. The first section, concerning body, in English works, (note 8), I, 531.

138. René Descartes, Principia philosophiae, (Amsterdam, 1644). This can be consulted in Oeuvres, (note 7), vol. VIII.

139. Sir Kenelm Digby, Two treatises. In the one of which the nature of bodies; in the other the nature of mans soul is looked into: in way of the discovery of the immortality of reasonable souls, (Paris, 1644).

NOTES TO CHAPTER 3

1. Sir Kenelm Digby, Two treatises. In the one of which the nature of bodies; in the other the nature of mans soul is looked into: in way of the discovery of the immortality of reasonable souls, (Paris, 1644). Hereafter cited as Digby, Treatises.


4. The most obvious example of this kind of attitude is R.H. Kargon, Atomism in England from Rariot to Newton, (Oxford, 1966), 70-3; especially 72-3.

5. The quoted phrase is taken from Webster's, Great Instauration, (note 3), p. 485. Early in his career, Webster did some pioneering work on the predominantly Catholic circle of natural philosophers working with Richard Towneley in Lancashire. Webster used his researches into this group to raise his voice against the Merton thesis and to criticize Christopher Hill's Intellectual origins, (note 5) for taking too simplistic a view of things. See, C. Webster, 'Richard Towneley (1629-1707), the Towneley group and seventeenth-century science', Transactions of the Historic Society of Lancashire and Cheshire, 118, (1966), 51-76; p. 75-6. By the time he came to write The Great Instauration, however, Webster had dismissed the Towneley circle and all Catholics, regarding them as mere dilettantes whiling away their time.

6. Webster has said of the Puritans that 'it can be shown that their scientific beliefs were framed with conscious reference to their religious views, each section within the Puritan sphere of influence developing a scientific outlook consistent with its doctrinal position', (Great Instauration, p. 503-4). He believes, therefore, that they provide 'an invaluable case study' for the historian by virtue of 'their pronounced attention to scientific matters and the explicit manner in which they articulated their ideas about religion, society and the natural world', (Ibid., 504). What I hope to show in this chapter is that precisely the same statements could be made about Digby, his close associate Thomas White and their circle, known as the Blackloists.

7. The Blackloists played an important part in the history of English Catholicism but, in spite of this, they have largely been ignored by historians. Even their leader, Thomas White is surprisingly little studied in view of his stature among his contemporaries. There are a number of brief treatments of his life and work in published sources. These include: Charles Dodd, The Church history of England, (Brussels, 1742), III, 285-8 and 350-6; H.W. Jones, 'Thomas White (or

The other known members of the Blackloists are, with one exception more obscure: Henry Holden (1596-1662), Peter Fitton (1602-1657), E. Tyrrel (1621-1676), and H. Ellis (d. 1676). There is some information about these thinkers in Anstruther's dictionary cited above. The only other member of the group to make a name for himself as a philosopher is also little studied: John Sergeant (1621-1707). Sergeant was an ardent controversialist who came to the fore after the Restoration. I hope to examine the later fortunes of the Blackloists and the ideas of Sergeant at some future date. Meanwhile the best treatment of his thought can be found in G.H. Tavard, The seventeenth-century tradition: a study in recusant thought, (Leiden, 1978), 219-45 (see also pp. 180-96 for a discussion of Henry Holden).

8. Sections 1, 2, 3 and 5 of this chapter have appeared in slightly different form in J. Henry, 'Atomism and eschatology: Catholicism and natural philosophy in the interregnum', British Journal for the History of Science, 15, (1982), 211-39.

9. There are a number of sources for Digby's biography besides the useful Biographia britannica and Dictionary of national biography articles. These include:


11. See R. T. Petersson, *op. cit.*, (9), 342; and J.M. Lewis, *op. cit.*, (7), which provides the only protracted attempt to assess this partnership so far.


15. Franciscus, a *Sancta Clara [Christopher Davenport], Deus, Natura, Gratia, sive tractatus de praedestinatione, de meritis & peccatorum remissione, seu de justificatione & denique de sanctorum in vocatione, Ubi ad trutinam fidel catholicae examinatur confessio anglicana etc.*,
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(Lyon, 1634). For a complete study of Christopher
Davenport see J.B. Dockery, op. cit., (13).
Chapters 4 and 5 deal with Deus, Natura, Gratia,
pp. 62-93, and see also Appendix D, pp. 146-149.
For a brief contemporary account of Davenport's
work see Richard Baxter, A key for Catholics to
open the juggling of the Jesuits ... a new edition

16. John Sergeant, An account of the Chapter erected
by William, titular Bishop of Chalcedon, and
ordinary in England and Scotland, with preface
and notes by W. Turnbull, (London, 1853).

17. Letter from Laud to Digby, March 27, 1636. Reprinted
in William Laud, The history of the troubles and
tryal of the most reverend Father in God, and blessed
martyr, William Laud, Lord Archbishop of Canterbury ... 

18. In that year, or perhaps earlier, White and Chillingworth
debated Catholic infallibility in Digby's lodgings.
See George Digby, Letters between the Lord George
Digby and Sir Kenelm Digby kt. concerning religion,
(London, 1651), p. 85. Thomas Birch in his 'Life'
of Chillingworth dates this meeting in 1635,
Chillingworth Works, (London, 1820), pp. 4-7, but
Lewis, op. cit., (7) argues that it must have been
between July 1637 and January 1638, p. 60.


20. Thomas White, Religion and reason, mutually
corresponding and assisting each other, (Paris, 1660), p. 25.

21. Thomas White, A letter to a person of honour ... 
in vindication of himself and his doctrine, (1659),
unpaginated /p. 18/.

22. Thomas White, An answer to the Lord Faulklands
discourse of infallibility, reprinted in Lucius
Cary, Viscount Falkland, A discourse of infallibility
with Mr. White's answer to it, and a reply to him,
answer was first published in 1651 but must have
been written prior to 1637, see Lewis, op. cit.,
(7), 59.

23. Kenelm Digby, Conference with a Lady about choice
of religion, (Paris, 1638), reprinted (London, 1969),

25. See note 18 above.

26. Lucius Cary, Reply, p. 65, 82, 187. Another important aspect of the debate between Falkland and Chillingworth on the one hand, and White and Digby on the other, arose from the rational scepticism of the two Protestants, as opposed to the firm belief in the possibility of absolute knowledge professed by the two Catholics. I do not intend to deal with this here but see Southgate, op. cit., (7), chapters 5, 6, 9 and passim. For the background to the scepticism of Falkland and Chillingworth see H. R. McAdoo, The spirit of Anglicanism: a survey of Anglican theological method in the seventeenth century, (London, 1965), Chapter 1, pp. 1-23; R.H. Popkin, The history of scepticism from Erasmus to Descartes, revised edition (New York, 1968); and G.H. van Leeuwen, The problem of certainty in English thought, 1630-1690, (The Hague, 1963).

27. Thomas White, Peripatetical institutions: in the way of ... Sr. Kenelm Digby: the theoreticall part, (London, 1656), p. 196. This work first appeared in Latin: Institutionum peripateticarum, (Lyon, 1646). As the title indicates White draws heavily upon Digby's Treatises but he expands the scope of his own work to include certain cosmological, meteorological and geophysical phenomena.


29. Interest in this topic seems to have been inspired by the pioneering work of Norman Cohn in 1957, now re-issued as Norman Cohn, The pursuit of the millennium: revolutionary millenarians and mystical anarchists of the middle ages, revised and expanded edition, (London, 1970). Works which concentrate on these themes in seventeenth-century England include: J. F. Wilson, Pulpit in Parliament: puritanism during the English civil wars, 1640-1648, (Princeton, 1969); W.M. Lamont, Godly rule: politics and religion 1603-1660, (London, 1969); Peter Toon, (ed.), Puritans, the millennium, and the future


32. Ibid., 33, 34.

33. Ibid., 34.

34. Ibid., 36

35. Ibid., 37.

36. See, for example, Jeremy Taylor, The liberty of prophesying, (London, 1648), pp. 84-5, where he denies the authority of Papias and other early chiliasts. The unorthodoxy of these ideas may also explain why Chillingworth's refutation of White remained unpublished during his life-time. See also below, pp. 106-108.

37. Jean Calvin, Institutes of the Christian religion, translated by John Allen, 3 vols., (London, 1813). Book III, chapter 25, section 6, p. 478. It is not necessary to distinguish here between the Calvinist and Aminian or Laudian Anglicans who have been delineated by Nicholas Tyacke, op. cit., (12). Tyacke points out that Anglicanism in the early part of the seventeenth century was doctrinally Calvinist, 119-129 (see also McAdoo, op. cit., (40), pp. 21, 24-30), but this was superseded by Aminianism with the rise of the Laudian faction, after Charles I came to the throne.
The Arminian rejection of Calvinist doctrine was centred on predestination, however, and it seems that Laudian Anglicans did not differ from Calvin on the issues of eschatology. This is certainly the case with Jeremy Taylor, cited below, and is also true of Henry Hammond, one of the leading Laudians: H. Hammond, The Works, (ed.), by W. Fulman, 4 vols., (London, 1684), I, 703; III, 363, 855-61. On Hammond see J.W. Packer, The transformation of Anglicanism, 1643-1660, with special reference to Henry Hammond, (Manchester, 1969).

41. The possibility of a reprieve would have to be ruled out to avoid similarities with the Catholic concept of purgatory.
42. Jeremy Taylor, Great exemplar, p. 171. This notion was regarded to be heretical, however, in Thomas Edwards, The third part of Gangraena, or a new and higher discovery of the errors, heresies, blasphemies, and insolent proceedings of the sectaries of these times ..., (London, 1646), p. 8.
44. Charles Webster refers to the tradition of 'providential history', Great Instauration, (3), 1-6.
45. See above p. 74 and Southgate, op. cit., (7), p. 1 and passim. White continually emphasised the use of reason in order to get at the truths of scripture and tradition. This can be seen in the titles of two of his works: Religion and reason mutually corresponding and assisting each other, (Paris, 1660 ?); and Devotion and reason. First essay wherein modern devotion for the dead is brought to solid principles and made rational, (Paris, 1661). White, like others in the seventeenth century (notably Hobbes and Descartes) believed that rigorous reasoning could be ensured by following the axiomatic method of Euclidean geometry. There
are numerous examples of this method in the work of White. Perhaps the most interesting example for the historian of science is his *Appendicula tentans solutionem problematis Toricelliani de subsistentia hydrargyri in tubo superne sigillato*, (London ?, 1663), (appended to Scirri, see note 122 below). But see also his *Euclides physicus, sive de principiis naturae, stoecheida etc.*, (London, 1657); and *Euclides metaphysicus, sive de principiis sapientiae, stoecheida etc.*, (London, 1658). For a fuller discussion of this aspect of White's work see H.W. Jones, *Leibniz' cosmology and Thomas White's, Euclides physicus*, Archives internationales d'histoire des sciences, 25, (1975), 277-303. For a general survey of this important topic see H. Schüling, *Die Geschichte der axiomatischen Methode in 16 und beginnenden 17 Jahrhundert*, (Hildesheim, 1969).


51. Ibid., sig. u.
52. Ibid., 443-445.
53. Ibid., 445.
54. Digby, Observations, p. 17.
55. Ibid., 41.
56. Unfortunately, Digby never explicitly considers how a soul can be purged when it is conjoined to the body. It is fairly clear, however, that he believes the soul to become capable of change in some way while established in the body.
58. Thomas White, Villicationis suae de medio animarum statu ratio episcopo Chalcedonensi reddita a Thoma Anglo ..., (Paris, 1563). This appeared in English as: The middle state of souls from the hour of death to the day of Judgement, (1659), and this edition has been used here. The ideas expressed in this work are reiterated throughout White's subsequent work. See especially: The state of the future life, and the presents order to it, (London, 1654), and Notes on Mr. F.D.'s result of a dialogue concerning the middle state of souls, (Paris, 1660).
59. White, Middle state, p. 37.
60. Ibid., p. 260.
61. Ibid., p. 97.
63. White, *Middle state*, p. 153. Cf. note 57 above. White's psychological interpretation of the suffering endured by the soul after death is very similar to the view expressed by the ranter Jacob Bauthumley in *The light and dark sides of God*, (London, 1650). See N.T. Burns, *op. cit.*, (43), p. 84; and Cohn, *op. cit.*, (29), pp. 305-6. Such ideas were fairly common among the radical protestant sects according to Christopher Hill, *The world turned upside down: radical ideas during the English revolution*, (Harmondsworth, 1975, pp. 175, 177. This gives further confirmation of my argument that White's theology was capable of absorbing radical ideas and integrating them with more orthodox beliefs. It should be remarked, however, that these ideas were not totally revolutionary but can be traced back to Origen and other early Fathers. See D.P. Walker, *The decline of hell: seventeenth-century discussions of eternal torment*, (London, 1964), pp. 61-63.

64. White, *Middle state*, 103-4.

65. Ibid., 154.

66. Ibid., 260.

67. Ibid., 5-6.

68. That White hoped to convince his fellow Catholics as much as Protestants is evident from his dedications of the book to Richard Smith, the Bishop of Chalcedon.

69. S. W., *A vindication of the doctrine contained in Pope Benedict XII, his Bull and in the General Council of Florence under Eugenius IIII concerning the state of departed souls .... Wherein the progress of Master White's lately minted Purgatory is laid open and its grounds examined etc.*, (Paris, 1659), 8.

70. R. Pugh, *Blackloe's cabal*, (full citation in note 79 below), from 'The epistle to the Catholic reader', unpaginated /page 6/.


1670), 8, singles out indulgences as a 'primary occasion' of the Reformation.

74. The most detailed sources so far are Bradley, *op. cit.*, (7); Southgate, *op. cit.*, (7); Lewis, *op. cit.*, (7); and Petersson, *op. cit.*, (9).

75. Petersson, *op. cit.*, (9), 151-2. See also Henrietta Maria, *A copy of 1. The Letter sent by the Queens majestie concerning the collection of the recusants mony for the Scottish warre, Apr. 17 1639. 2. The letter sent by Sir K. Digby and Mr. Montague concerning the contribution ... etc.*, (London, 1641).


77. Petersson, *op. cit.*, (9), 216.


79. R. Pugh, *Blacklo's cabal discovered in severall of their letters clearly expressing Designs inhumane against regulars, unjust against the laity, scismatical against the Pope, cruel against orthodox clergymen, and owning the nullity of the chapter, their opposition to the episcopal authority*, (Douay?, 1680).

80. Ibid., 33-34 and 36-40. For an account of the Blackloist opposition to the Jesuits see R. I. Bradley, 'Blacklo and the counter-reformation: an inquiry into the strange death of Catholic England', in C. H. Carter (ed.), *From the Renaissance to the Counter-Reformation: essays in honour of Garret Mattingly*, (London, 1966), 348-370. It is evident from Gregorio Panzani, *op. cit.*, (14), that the Jesuits were the major stumbling block to any ecumenical movements. For surprising indications as to just how far the Blackloists were willing to go in their opposition to the Jesuits see M.V. Hay, *The Jesuits and the Popish plot*, (London, 1934). See also note 97 below.

82. Ibid., 251. See also the articles on Digby in Biographia Britannica, and DNB. Digby's close association with Cromwell is perhaps not as surprising as it may seem at a superficial glance. Cromwell seems to have been more inclined to grant freedom of worship than most of his contemporaries. See R.S. Paul, The Lord Protector: religion and politics in the life of Oliver Cromwell, (London, 1955), 327-8 and 331-3; and Dockery, op. cit., (27), 124-126.


86. Seth Ward and John Wilkins, Vindiciae academiærum, (Oxford, 1654). This included an Appendix concerning what M. Hobbes and M. Dell have published on this argument. See Debus, op. cit., (83). Hobbes was attacked because of what was thought to be his atheism. The mechanical philosophy of Digby and White escaped these charges.

87. Ward, Appendix, 53.


91. Thomas White, The grounds of obedience and government,
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(London, 1655), reprinted (Farnborough, Hants, 1968). Previously this work has been dated as 1649, see Jones, 'New data', (7), 381-388. However, I have accepted the later date of 1655 which is proposed by G. Anstruther, op. cit., (7), II, 351; and clearly established in B.C. Southgate, 'Thomas White's Grounds of obedience and government: a note on the dating of the first edition', Notes and queries, 28, (1981), 208-9.


92. White, Grounds, 9.

93. Ibid., 47.

94. Ibid., 147.

95. Ibid., 152.


97. Having tried to gain toleration from Charles I and Oliver Cromwell, the Blackloists evidently petitioned Charles II in a similar manner. Gilbert Burnet tells us of their efforts in Bishop Burnet's history of his own time; with the suppressed passages of the first volume, and notes by the Earls of Dartmouth and Hardwicke and Speaker Onslow hitherto unpublished ... 7 vols., (Oxford, 1823), I, 335. The passage reads: 'the papists went on more warmly, and were preparing a scheme for a toleration for them. And one part of it raised great disputes among themselves. Some were for their taking the oath of allegiance, which renounced the pope's deposing power. But all those that were under a management from Rome refused this. And the internuncio at Brussels proceeded to censure those that were for it, as enemies to the papal authority. A proposition was also made for having none but secular priests tolerated in England, who should be under a bishop, and under an established government. But that all the regulars, in particular all Jesuits, should be under the strictest penalties forbid the kingdom.

The earl of Clarendon set this on; for he knew well it would divide the papists among themselves. But, though a few honest priests such as Blacklow, Serjeant, Caron and Walsh, were for it, yet they could not make a party among the leading men of
their own side. It was pretended, that this was set on foot with a design to divide them, and so to break their strength. This took place in December 1662 and it shows clearly that although White was still active he was not so influential as he had been earlier. White retreated increasingly into the background after this, although he did continue to write and publish. One important factor in his fall from power was, no doubt, the increasing condemnation of his work by the Holy Office (his works were censured in 1655, 1657, 1661 and 1663). See Lewis, op. cit., (7), 230; Southgate, op. cit., (7), 10; and Anstruther, op. cit., (7), II, 351.

98. R. I. Bradley, op. cit., (7) and (80).

99. Thomas White, Tabula suffragiales determinandis fidel ab ecclesia catholica fixae ..., (London, 1655). White's denial of Papal infallibility was by no means as unprecedented as many of his other beliefs. In fact it was a much disputed opinion within the Roman Catholic Church at that time.

100. Biographia britannica article (on Digby), 194 (in the footnotes); and (on White) Richard Baxter, Reliquae Baxterianae: or, Mr Richard Baxter's narrative of the most memorable passages of his life and times, (London, 1696), 118. For an interesting account of another group of heterodox Catholics who shared some of their theological doctrines with the Puritans but who were also dismissed as straightforward Catholics by English Protestants see: Robin Briggs, 'The Catholic Puritans: Jansenists and Rigorists in France', in D. Pennington and K. Thomas, (eds.), Puritans and revolutionaries: essays in seventeenth-century history presented to Christopher Hill, (Oxford, 1978), 333-54.

101. R. I. Bradley, op. cit., (80), especially pp. 351-2; Petersson, op. cit., (9), 223; Dockery, op. cit., (13), 124. White's contempt for the Jesuits (see notes 80, 97 above) can be partially explained by their opposite views as to the meaning of counter-reform.


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105. Digby, Treatises, 343. In fact Digby's atoms are not indivisible nor are they separated from one another by void space. Digby, like most of his contemporaries accepted all the Aristotelian arguments against atoms and the void. See Chapter 1, sections 1, 2, 3.

106. Ibid.

107. See Kargon, op. cit., (4), 72-3. In fact, White and Digby were very much in the vanguard of natural philosophical innovators of the seventeenth century. White's De mundo (note 7 was heavily indebted to Galileo, Digby was one of the earliest advocates of William Harvey's theory of blood circulation (Fulton, op. cit., note 9). Both men were members of Mersenne's circle in Paris and fully acquainted with the ideas of Hobbes, Gassendi and Descartes. This may be seen by consulting the index to M. Mersenne, Correspondance, ed. by P. Tannery and C. de Waard, 13 vols. (Paris, 1955-77), and R. Descartes, Correspondance, ed., by C. Adam and G. Milhaud, 8 vols. (Paris, 1936-63). Note also that Digby discusses one of Gassendi's atomist arguments which was unpublished at that time in Treatises, 154-5.


110. The dispute between monistic and pluralistic cosmogonies is extremely difficult for the modern mind to follow and Zeno's paradoxes are often hard


112. Ibid., 371, 405. See also, Aristotle, Physics, 187b22-34.

113. Aristotle, Physics, 187b30-34.

114. Ibid., 187b20-22.

115. Van Melsen, op. cit., (109), 47.

116. Ibid., 59-60.


118. Franciscus Toletus, In libris Aristotelis de generatione et corruptione commentario una cum questionibus, (Cologne, 1585), 340.

119. J.C. Scaliger, Exotericarum exercitationum liber quintus decimus, de subtilitate, ad Hieronymum Cardanum, (Paris, 1557); J. Bodin, Universae naturae theatrum in quo rerum omnium effectrices cause, & fines contemplantur & continue series quinque libris discutiuntur, (Lyon, 1596). Others include Sennert (see next note); Sebastian Basson, Philosophiae naturalis adversus Aristotelem libri XII in quibus abstrusa veterum physiologia restauratur et Aristotelis errores solidis rationibus refelluntur, (Geneva, 1621); and David van Goorle, Exercitationes philosophicae, (Leyden, 1620). See Van Melsen, op. cit., (109), 13-7, and 89-91; T. Gregory, 'Studi sull' atomismo del seicento I: Sebastiano Basson', and 'Studi sull' atomismo del seicento II: David van Goorle e Daniel Sennert', Giornale critico della filosofia italiana, 42, (1964), 38-65, and 45, (1966), 44-63. See also Lasswitz, op. cit., (2).
120. Van Melson, *op. cit.*, (109), 81-9, and Gegory, *op. cit.*, (119), part II. A number of Sennert's works were translated into English and the third edition of his *Epitome naturalis scientiae* was published in England, (Oxford, 1632). This was translated into English as *Thirteen books of natural philosophy*, (London, 1659). For indications of his influence in England see D.B. Sailor, 'Moses and atomism', *Journal of the history of ideas*, *25*, (1964), 3-16.

121. I have already argued in Chapter 1, that the matter theory of the new philosophy was very much indebted to Aristotle's arguments. This was also true of Digby's theory. See note 105 above.

122. Thomas White, *Scirri, sive sceptices et scepticorum a jure disputationis exclusio*, (London?, 1663). I have used the English edition: *An exclusion of scepticks from all title to dispute: being an answer to the vanity of dogmatizing*, (London, 1665), p. 52. See also the extended title of White's *Peripatetical institutions*, note 27 above.

123. Joseph Glanvill, *The vanity of dogmatizing: or, confidence in opinions manifested in a discourse of the shortness and uncertainty of our knowledge*, (London, 1661). See also *idem, Scepsis scientifica: or confess ignorance the way to science ... with a reply to the exceptions of the learned Thomas Albius*, (London, 1665).


127. Joseph Glanvill, *Scire/i tuum nihil est; or, the authors defence of the Vanity of dogmatizing*, (London, 1665), 36.

128. I have said little here about White's use of Scripture. One of the most interesting manifestations of White's belief that his rationalist natural philosophy was fully in agreement with the Scriptures is to be found in his *Theological appendix, of the beginning of the World*. This appendix to his *Peripatetical institutions*, (London, 1656) (which first appeared in Latin in 1646) seeks to show that the Biblical account in *Genesis* is in accord with the principles
of mechanical philosophy as expounded by White. It is clear that White's work pre-empts the more famous Thomas Burnet, Sacred theory of the Earth, (London, 1681-9) - in which Burnet tried to explain the events of Genesis in Cartesian terms - by over thirty years. I have already indicated that White regarded his own rational method to be as rigorous as that of Euclid. See note 45 above.

129. Webster, Great Instauration, (3), 1-31, 505-9, 517, 520.

130. Ibid., 507, 520.

131. The obvious examples of such thinkers are to be found among the ranks of the Fifth Monarchists. See B.S. Capp, op. cit., (29).

132. P. Toon (ed.), op. cit., (29), passim, especially 8-41 and 104-14. As a further example consider Henry Hammond, A premonition concerning the interpretation of the Apocalypse, in which he declares that the incidents foretold by John all happened very quickly after Christ's resurrection, and even that some of them had already occurred by the time John wrote: The works, (London, 1684), III, 855-61, especially 857. For a brief survey of other orthodox views see I.H. Murray, The Puritan hope, (London, 1971), XVI-XVIII, and 39-51.

133. P. Toon (ed.), op. cit., (29), 17, distinguishes between premillennialism, postmillennialism and amillennialism. Paul Christianson, op. cit., (29), 7, however, warns that these and other distinguishing terms are in danger of causing even greater confusion. I can readily agree with this and I must express my gratitude to Dr Colin Russell for helping me to make sense of these abstruse matters. Christianson recommends the use of the wider term 'apocalyptic' and reserves the term 'millennial' (or 'millenarian') to refer to the notion of 'a future, collective, imminent transformation of life on Earth'. B.S. Capp is always careful to distinguish between apocalypticism and millenarianism and, essentially, I am in agreement with his position. See, B.S.Capp, 'Godly rule and English millenarianism' and 'The millennium and eschatology in England', in C. Webster (ed.), op. cit., (3), 386-98, and 427-34. There is one small point of difference between us, however. His characterisation of apocalypticism
as 'pessimistic' and millenarianism as 'optimistic' (ibid., 387) is completely subjective and seems to illustrate what could be called 'unbeliever's chauvinism'. Dr. Capp seems to be incapable of seeing that a godly man could look forward to the Last Day with great optimism.


136. Webster, Great Instauration, (3), 505.

137. A number of other writers have allowed themselves to be confused by failing to make the necessary distinction between apocalypticism and millenarianism. For example, J.R. Jacob, Robert Boyle and the English revolution: a study in social and intellectual change, (New York, 1977), 125, notices that Boyle is too orthodox a thinker to desire the political revolution implied in millenarianism and yet he continues to speak of Boyle's 'millenarianism' throughout the book. Similarly, M.C. Jacob, The Newtonians and the English revolution, 1689-1720, (Hassocks, 1976), 104 and elsewhere, seems surprised to find 'millenarianism' advocated by many orthodox thinkers. In fact there is no contradiction: the orthodox thinkers she mentions looked forward to the complete destruction of their world followed by the establishment by God of a 'new heaven and a new earth' in which they would be living eternally in heavenly bliss. This is not a political vision but a religious one and it is definitely not millenarianism. Burnet, therefore, was not millenarian (contrary to her statement at p. 116), nor was Hobbes, (p. 104), and nor was Evelyn (p. 122). Christopher Hill, most recently in Some intellectual consequences of the English revolution, (London, 1980), 58-61, also sees all shades of apocalyptic thought merely in terms of the 'practical politics' of millenarianism (p. 58) or in terms of a Baconian 'theory of progress' (p. 59).
138. Robert Boyle, Some physico-theological considerations about the possibility of the Resurrection, Works, 6 vols. (London, 1772), IV, 191-202; Thomas Burnet, op. cit., (118); John Evelyn left among his manuscript papers at Christ Church, Oxford, a tract 'Concerning the millennium' (Evelyn MS 35) in which he insisted that he spoke 'Not as the Millenaries of old' about a thousand year period on this earth, but about an eternal period in a 'Renewed Heaven and Earth to come' (f. 2). The visions of Burnet and Evelyn are similar in important respects to that of Hobbes who might also have been included in this list (see note 134 above).


140. Letter from Hartlib to Boyle, May 8, 1654, in Boyle, Works, VI, 87. On ecumenism in Hartlib's circle see, for example, J.M. Batten, John Dury: advocate of Christian reunion, (Chicago, 1944). Dury was one of the leading members of the circle.


142. I have often been puzzled by this myself. So has Margery Purver, The Royal Society: concept and creation, (London, 1967), 157-8.


150. The phrase was coined, I believe, by R.H. Popkin. See Popkin, *op. cit.*, (26). For accounts of the rule of faith controversy and its implications for the notions of truth and certainty in Anglican thought see Van Leeuwen, *op. cit.*, (26), McAdoo, *op. cit.*, (26), and Orr, *op. cit.*, (13). See also W. Chillingworth, *The religion of Protestants a safe way to salvation*, (Oxford, 1638), which is the most renowned work in this tradition.


152. See above p. 84.


155. See above, Chapter 2, pp. 44 - 45

156. After all, as we have seen (pp. 66 ) St. Augustine was an exponent of light metaphysics. Even so, although Digby often cites earlier authorities he never enlists the support of light metaphysicians. For a list of authorities cited by Digby see Petersson, *op. cit.*, (9), 341-2, note 127.


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162. **Ibid.**, 38. See also p. 62 where we are told that fire 'multiplyeth exceedingly in its source'. And that 'It must of necessity followeth that it shooteth out in great multitudes, little small partes into the ayre and into other bodies circumfused, with great dilation'. On the autodiffusion of light in earlier thinkers see Chapter 2, pp. 55-6.


164. Chapter IX, pp. 63-75.

165. **Treatises**, 39. For Aristotle's theory of light see *De anima*, II, 7 and *De sensu*, VI.

166. **Treatises**, 53.

167. See Chapters 2 and 4.


170. **Ibid.**, 41 and 59. In his own discussion in favour of the finite speed of light (see above pp. 61 ), in The little treatise (note 154). Hobbes also dismisses this argument pp. 201-2.

171. **Treatises**, 38 and 137. Digby does not mention any of these 'Philosophers' by name but it is reasonable to assume that he had neo-Platonists in mind.

172. **Treatises**, 76, and 143; see also p. 91.


174. This is Chapter XIV, **Treatises**, 116; see also 71.

175. **Treatises**, 77.

176. **Ibid.**, 80.

177. **Ibid.**, 88.

178. In Chapter IV: 'Of the foure first qualities: and the foure Elements', pp. 26-32, Digby argues that when a body's density overcomes the force of gravity acting upon it the body will cohere and will be regarded as a dense dry body. If gravity overcomes the body's density, however, the body will not
cohere but will collapse and run down to as low a level as it can - this characterises a dense wet body, pp. 27-8. For a further discussion of this see Dobbs, op. cit., (2), part I.

179. Treatises, 96.


183. I have concentrated on Digby's natural philosophy as expounded in Two treatises because it is the earliest complete version of the Blackloist system. Precisely similar ideas occur in White's subsequent works however. See, for example, Peripatetical institutions, op. cit., (27), p. 53 where he relies upon the autodiffusion of fire.

NOTES TO CHAPTER 4

1. In Chapter 3 I am not necessarily claiming that they were the first to do this anywhere, though I believe they were the first to do so in England. There are strong grounds for believing that Mersenne, Gassendi, Pierre, and Descartes were also perfectly explicit in their use of science for ideological purposes. On this see John A. Schuster, 'Descartes and the scientific revolution 1618-1634: an interpretation', (Ph.D. thesis, Princeton University, 1977).
2. See Chapter 6, Sections 1 and 4 above, where I argue that the experimental method was developed partly as a response against dogmatic rationalism.


5. De corpore, 'Epistle dedicatory', pp. VIII-IX.

6. English works, II, p. XX.


11. [Seth Ward], Vindiciae academiarum containing some


16. Ibid., 305-6.

17. Ibid., 306-7.

18. Ibid., 307. See also 489-90; De corpore, 412; and Leviathan, 385.


24. See, for example, *Behemoth*, *English works*, VI, 236-7; *De corpore*, 412; *Seven philosophical problems*, *English works*, VII, 5; and *Leviathan*, 242. See also below pp. 140.

25. See above pp. 92-3.


28. Chapter 3, Sections 2 and 3.


30. *Ibid.*, 241. See also *English works*, IV, 390 and 395-6 where Hobbes implies that heresy arises from the application of philosophy to theological matters.


33. *Leviathan*, 334 and 367-80. It is also reminiscent of Stubbe's and Barlow's charges against the Royal Society and the new philosophy in general. See above pp. 111-14.


36. See above pp. 74.

37. *Leviathan*, 396.


40. Quoted in Brandt, *op. cit.*, (12), 180.
42. See Chapter 1, Section 3. On Hobbes' concept of space and place see Brandt, *op. cit.*, (12), 251-7.
43. See Chapter 2 above.
44. *Leviathan*, 375.
45. *De corpore*, 531.
46. On the influence of and rivalry with Descartes see Brandt, *op. cit.*, (12), 129-42; 160-1; 315, 325; and 370.
47. *Ibid.*, 104-11
49. See Chapter 2 above.
51. Brandt, *op. cit.*, (12), 170; White's *De mundo examined*, (10), 208-11.
52. Brandt, *op. cit.*, (12), 168-9. See also note 38 above.
55. *Leviathan*, 375.
56. White's De mundo examined, (10), 101.

57. William Harvey, Exercitatio anatomica de motu cordis et sanguinis in animalibus, (Frankfurt, 1628). I have used the translation by G. Whitteridge: W. Harvey, An anatomical disputation concerning the movement of the heart and blood in living creatures, (Oxford, 1976), 76. The quotation appears in Chapter 8.

58. In this respect Hobbes' philosophy is very similar to the ideas of Sir Kenelm Digby discussed above in Chapter 3, Section 6. See also note 67 below.

59. Harvey, op. cit., (57), Chapter 16, p. 116. For a full account of William Harvey's vitalistic ideas see Walter Pagel, William Harvey's biological ideas: selected aspects and historical background, (Basel and New York, 1967), 251-82; and idem, New light on William Harvey, (Basel etc., 1976), 21-2, 34-6 and passim.

60. Harvey, op. cit., (57), Chapter 8, p. 76.


62. Ibid., 329-33.

63. Ibid., 328, see also 333. On circular inertia in Galileo see Galileo Galilei, Dialogue concerning the two chief world systems - Ptolemaic and Copernican, trans. by Stillman Drake, (Berkeley and Los Angeles, 1967), 18-19, 28-9, 31-2. See also S. I. Mintz, 'Galileo, Hobbes and the circle of perfection', Isis, 43, (1952), 98-100. It is possible that Hobbes' infatuation with perfect circularity may owe something to the earlier influence of William Harvey. On the role played by notions of circularity in Harvey's work see Pagel, Harvey's biological ideas, (59), 89-124; and New Light, (59), 37-41.

64. Hobbes was mistaken in this assumption. See below PP. 153-5.


66. If further evidence is required for the influence of Harvey on Hobbes consider the fact that in his earliest writings Hobbes regarded the brain as the seat of the senses (see, for example, the discussion
in Part III of *The little treatise* in Chapter 2, Section 1). After 1646, however, he regarded the heart as the seat of sensation (Brandt, *op. cit.*, (12), 88). Just as Hobbes' theory of light changed to a conception of pulses emitted by a pulsating Sun so the heart became for Hobbes, as it was for Harvey, the seat of sensation.

67. Remember this is similar to Digby's ideas discussed above, Chapter 3, Section 6. Apparently Hobbes also shared this view with the contemporary neo-Platonist, Thomas Vaughan, (1622-1666). Henry More in his polemic with Vaughan objected to Vaughan's notion of a 'pulse of the world' and asked where was the heart whose systole and diastole produced this pulse. See H. More, The second lash of Alazonomastix laid on in mercie upon that stubborn youth Eugenius Philathes: or a sober reply to a very uncivill answer to certain observations upon Anthropsophia theomagica and Anima magica abscondita, (London, 1651), p. 67. Small wonder that Hobbes wanted to replace his theory with a more mechanistic one if he found himself in company with latter day neo-Platonists like Vaughan.

68. *De corpore*, 320.

69. Ibid., 321-4.

70. Ibid., 467-70; 448-50; 471-4; 470-1; and 474-8.

71. Ibid., 477.


73. Brandt, *op. cit.*, (12), 304.

74. Ibid., 367.

75. Ibid., 339, 327, 368. See also above pp. 148-9.


77. Ibid., I. 205.

78. See Chapter 6, section 2.


81. See *De corpore*, 447 and 431 for examples of Hobbes' reliance on the Deity.

82. Boyle, *Works*, (76), I, 204-5.


84. It should be noticed that even Boyle only suggests that there is a methodological link between the different facets of Hobbes' philosophy. He does not suggest, unlike Watkins and Spragens, that there is a more intimate connection. See note 8 above.


86. See above pp. 135-41.

87. It is my contention, as will be seen, that Hobbes' *De corpore* is the only work of strict mechanism developed in England.

88. Brandt, *op. cit.*, (12), 129-42; 160-1; 315, 325; and 370.


should be supplemented by Rosaleen Love, 'Revisions of Descartes' matter theory in
Le monde', British journal for the history of
science, 8, (1975), 127-37. On Descartes as a
corpuscularian philosopher see Francesco Trevisani,
'La teoria corpuscolare in Cartesio', in U.
Baldini, G. Zanier, P. Farina, P. Trevisani,
Richerche sull' atomismo del seicento, (Florence,
1977), 181-223.

92. In what follows I draw heavily upon the work of
John Schuster, op. cit., (1), although the
interpretation is my own.

93. Schuster, op. cit., (1), 268 and 352. On this
aspect of Galileo's and Harriot's work see John
Henry, 'Thomas Harriot and atomism: a reappraisal',

94. C. de Waard, (ed.), Journal tenu par Isaac Beeckman
de 1604 à 1634, 4 vols. (The Hague, 1939-53), III,

95. Beeckman, Journal, (94), III, 74-5. I owe this
reference to Schuster but have provided my own
translation, I believe Beeckman was influenced
here by Al Kindi. See Chapter 2, Section 2.
This is only speculation so far.

96. Ibid., p. 100.


98. That is to say, magnets were common examples of
an evidently occult power which could operate
over distance. If their power could not be
explained it could easily be demonstrated by
experience. For more on this, see Chapter 6,
Section 4.

sizes and densities of the planets were invoked
to account for their different distances from
the sun.

100. See above, Chapter 2, Section 2 and Chapter 3,
Section 7.

101. Beeckman, Journal, (94), I, 28 and 201. See
also vol. III, 69.


107. Clearly Descartes was much quicker to see the fully mechanistic possibilities. Hobbes' *Little treatise* was written in 1630, he developed his systolic-diastolic concept of illumination about 1646 and arrived at his final version sometime between then and 1655.

108. We do not have Beeckman's own accusation but it is reported to Mercenne by Descartes in a letter of November, 1630. *Oeuvres*, I, 171. For further details see Schuster, *op. cit.*, (1).

109. See above pp. 144-5.


111. Full details of Descartes' theory of light are expounded in Schuster, *op. cit.*, (1), 272-354 and 665-749. It should be noted that Descartes sometimes spoke of light as analogous to moving balls. See *Le monde*, chapter XIV, articles 9 and 10.

112. Schuster, 280-1.


114. See above pp. 150-1.

115. *De corpore*, 206.

117. De corpore, 348-9. I suspect Hobbes' concept of conatus is indebted to Warner at this point. See above pp. 44.


119. Principles, Part III, article 34 in Oeuvres, IX, p. 117. See also article 36, ibid., 118; and ibid., V, p. 259.

120. Ibid., V, p. 259 and Principles, Part III, article 153, in Oeuvres, IX, p. 198.

121. Oeuvres, V, p. 259.

122. Ibid. These deviations from circularity were, of course, well known to Ptolemaic astronomy.


125. De corpore, 330-1.

126. Hobbes had demonstrated this previously: De corpore, 323-5.

127. Ibid., 331-2.

128. Ibid., 433-4. I have presented this as it appears in De corpore but it seems to me that Hobbes has made a mistake to the utter ruin of his theory. Surely the Earth should be closest to the Sun when its solid part is turned towards the Sun? As the solid part is the northern hemisphere it follows that the Earth should be closer to the Sun in the summer not the winter as he says.

129. De corpore, 435.

130. It is interesting to note that when Seth Ward accused Hobbes of plagiarising from Warner (see note 11 above) he had not seen Warner's papers himself but declared himself to be 'certainly informed by one who hath seen them'. The most likely informant, familiar with Hobbes'


NOTES TO CHAPTER 5

1. Such is the general consensus. I believe that Charleton's contribution to the development of science is much greater than has previously been recognised. In particular, I believe his contribution to the development of seventeenth-century medical theory has been vastly underrated. For the beginnings of a corrective to this state of affairs see T. M. Brown, 'The mechanical philosophy and the "animal oeconomy": a study in the development of English physiology in the 17th and early 18th century', (Ph.D. thesis, Princeton University, 1968).


3. To use the phrase of Paul Hazard in his classic work: La crise de la conscience européenne, (Paris, 1935).
4. R.H. Popkin, *The history of scepticism from Erasmus to Descartes*, (New York, 1964). This has now been up-dated as *The history of scepticism from Erasmus to Spinoza*, (Berkeley and Los Angeles, 1979) but I have been unable to consult this. H.G. van Leeuwen, *The problem of certainty in English thought, 1670-1690*, (The Hague, 1963).


6. I will go on to illustrate this probabilist philosophy of science in Chapter 6 also.


9. After publishing a number of Helmontian medical works, for example, Charleton turned to the mechanical philosophy in *The darkness of atheism dispelled by the light of nature: a physico-theological treatise*, (London, 1652).


12. Webster, *op. cit.*, (2), 360.

14. Quoted from C. Webster, _op. cit._, (2), 365. See also M. Nicolson, 'The early stage of Cartesianism in England', (note 2), 366 and 368.

15. Walter Charleton, _Darknes of atheism_, (note 9). Hereafter cited as _Darknes_.

16. Charleton, _Darknes_, sig. b3r.

17. Pierre Gassendi, _Animadversiones in decimum librum Diogenis Laertii qui est de vita, moribus, placitisque Epicuri_, (Lyon, 1649). Walter Charleton, _Physiologia Epicuro-Gassendo-Charltoniana_: or a fabric of science natural upon the hypothesis of atoms. Founded by Epicurus, repaired by Petrus Gassendus, augmented by Walter Charleton ... the first part, (London, 1654), reprinted (New York and London, 1966). The second, third and fourth books of the _Physiologia_ closely follow Gassendi's _Animadversiones_ but the first book is somewhat different and shows similarities with material not to appear in print until the publication in 1658 of Gassendi's _Syntagma philosophicum_, (Lyon, 1658). Clearly Charleton had access to this material in manuscript.


20. Henry More, _The apology of Dr Henry More_, (London, 1664), 482. See also the 'Preface general' to _Collection_, I, pp. IV-VI.

21. _Responsum H. Mori ad epistolam Claudii Clersemier_, _Collection_, I, 59. See also 'Preface general', _Collection_, I, pp. VI, XII, XVII-XIX.


23. Henry More, _An antidote against atheism: or, an
appeal to the natural faculties of the mind of man, whether there be not a God, (London, 1653). The third edition 'corrected and enlarged' appears in Collection, I, and has been used here.


26. Henry More, The immortality of the soul, so farre forth as it is demonstrable from the knowledge of nature and the light of reason, (London, 1659), reprinted in Collection, II.

27. See above, Chapter 3, Section 3.

28. On Digby see above, Chapter 3. Note also that Thomas White's De medio animarum statu, (Paris, 1653), had already appeared and was published in

29. Atheism is virtually impossible to track down at this time and yet men like More, Cudworth, Boyle, Charleton and many others were obsessed with what they took to be its proliferation. Much work needs to be done in this area before the seventeenth-century incidence of atheism can be properly assessed. Meanwhile see G. E. Aylmer, 'Unbelief in seventeenth-century England', in D. Pennington and K. Thomas (eds.), *Puritans and revolutionaries*, (Oxford, 1978), 22-46; K. Thomas, *Religion and the decline of magic*, (Harmondsworth, 1973), 127-8, 198-205; and M. Hunter, *op. cit.*, (10), 162-67.


32. For the current interpretations see note 7 above.

33. Burtt, *op. cit.*, (7); Koyré, *op. cit.*, (7).

34. See, for example, *Collection*, II, p. 3. On More's concept of extended souls see Koyré, *op. cit.*, (7), 117-23; and Burtt, *op. cit.*, (7), 127-33. More's ideas are entirely consistent with his Platonic outlook, see J. Henry 'Francesco Patrizi's concept of space and its later influence', *Annals of science*, 26, (1979), 549-75, pp. 569-71.


37. More speaks of the 'vehicles' of the soul as being material, so it could be argued that his views on the soul itself are strictly immaterialist. It seems to me, however, that the absence of a discussion of the soul independent of its vehicle merely underlines my argument.


42. Collection, II, 119. This is, of course, a misreading of Descartes' theory of light which is described in terms of a series of shocks transmitted through the medium of the second element and not as a body at all. However, Descartes does speak of light in terms of an analogy with moving balls and this may account for More's error. See R. Descartes, Le monde, Chapter XIV, articles 9 and 10 in Oeuvres, ed. C. Adam and P. Tannery, 12 vols. (Paris, 1897-1910), XI.

43. Collection, II, 119.

44. Collection, II, 154.

45. I am using the term 'materialism' in its older, philosophical sense to refer to the belief that all real entities are either composed of matter or are epiphenomena of matter. I do not use it in the economic sense.

46. Collection, II, 154.

47. See above, Chapter 3, Section 3.

48. Collection, II, 6-7.

49. See note 28 above.


51. It is not clear from the writings of the Blackloists how the soul may be tormented by feelings of guilt without the faculty of memory. It may be that they would refer feelings of guilt to 'understanding' and 'knowledge' which can be said to be independent of memory. More's explanation which includes the memory of evil deeds is much more immediately comprehensible.

52. Collection, II, 229-30. More is rather disingenuous in his discussion because he talks exclusively of the 'conflagration of the world' as 'an opinion
of the Stoicks' and is therefore able to avoid discussing the scriptural indications about the end of the world.

53. Collection, II, 234. More tells us that this is his rendering into English of a Pythagorean distich.

54. Collection, II, 7-8.

55. Henri Guerlac, *op. cit.*, (note 18) believes that Charleton invented the genre, p. 89.


58. *Darknes*, sig. a 2v.

59. *Darknes*, sig. a 3v.

60. *Darknes*, 47.


63. *Immortality*, 12.

64. Charleton seems to have made one or two enemies in his time. Most notably the first President of the Royal Society, Lord Brouncker. Charleton was initially very active in the Royal Society but suddenly drops completely out of the minutes in 1668. That this was due to some personal enmity which developed between Charleton and Brouncker is evident from a letter by Charleton to John Aubrey (February 4, 1671, British Library, Egerton MS. 2231). Similarly, it is evident from the entry in *Athenae oxonienses*, (note 11), IV, 752-6, that Anthony Wood had no love for Charleton. We do not know what 'enemies' he has in mind at this early stage of his career but he clearly believes them to exist. *Immortality*, 11-12.

65. *Immortality*, 78-9. This is effectively the outset of the discussion because the first dialogue, pp. 1-54, is a description of the state of natural philosophy in England, and the opening pages of the second dialogue are concerned with discussing Charleton's hypothetical method. On this last point see below pp. 199-201. For a discussion of the first dialogue see C. Webster, 'The College

66. Immortality, 82.

67. The influence of Descartes is clear on p. 103-4 and Digby is cited in the same places. On Gassendi's influence see 68-9.

68. Immortality, 180.

69. Walter Charleton, The harmony of natural and positive Divine laws, (London, 1662), sig. A6r; see also p. 16.

70. For a survey of this topic see Michael Hunter, 'The Royal Society and the origins of British archaeology', Antiquity, 65, (1971), 113-121, and 187-192.

71. Walter Charleton, Chorea gigantum: or, the most famous antiquity of Great Britain, vulgarly called Stone-Heng ..., (London, 1663), p. 3. This work is a response to an earlier study by the Royal Architect, Inigo Jones, (1573-1662), in which Stonehenge was alleged to be a Roman temple. Charleton argued that it was built by the Danes, 'when they had this Nation in subjection', as the ceremonial site for electing their 'Supreme magistrates' (sig. A3r and 36-7). Charleton's 'politick' designs in the work are spelled out in the laudatory poems which preface the book. Sir Robert Howard, (1626-1698) wrote (sig. A7r):

Nor is thy Stone-Heng a less Wonder grown,
Though once a Temple thought, now prov'd a Throne:
Since we who are so blessed with Monarchy,
Must gladly learn, from thy Discovery,
That great Respects not only have been found
Where Gods were worshipp'd but where Kings were Crown'd.

While his better-known brother-in-law, John Dryden, (1631-1700) puts it this way (sig. A6r):

Stone-Heng, once thought a temple, You have found
A Throne where Kings, or Earthly Gods, were crown'd.

These Ruins sheltered once his Sacred Head,
Then when from Wor'sters fatal field He fled;
Watch'd by the genius of this Kingly place,
And mighty visions of the Danish Race.
His refuge then was for a Temple shown:
But, he restor'd, tis now become a Throne.
notes pp. 195 - 198


74. In his account of English natural philosophy in the first dialogue of The immortality of the soul, Charleton claims that the Civil wars have discouraged men from the study of Theology and brought the Civil Law into contempt. The result is that most young scholars turned to physick, 'and how much that conduceth to real and solid Knowledge, and what singular advantages it hath above other studies in making men true philosophers; I need not intimate to you ...', p. 50.


76. J.A. Schuster, op. cit., (75), 428-430.


80. The best illustration of just how turbulent those years were is Christopher Hill, The world turned upside down, (Harmondsworth, 1975).
notes pp. 198 - 200


82. Henry More, Enthusiasmus triumphatus: or, a brief discourse of the nature, causes, kinds and cure of Enthusiasm, (London, 1656), reprinted in Collection, I. The quotation in fact gives the opening words of the treatise, p. 1. See also Michael Hunter, op. cit., (note 10), 180. The link between atheism and enthusiasm was that they were both seen as dogmatic positions but at the time he wrote Enthusiasmus triumphatus More himself was not fully aware of the dangers of dogmatism, as we shall see (below pp. 201).


84. Such a suspension of judgement was also in keeping with the older English theological tradition known as adiaphorism. The adiaphorists argued that some matters were 'indifferent' to salvation and the true faith. The position seems to have been developed by Philip Melanchthon (1497-1560) and introduced into England by John Frith (1503-1533) and Thomas Starkey (1499?-1538). The main intention of this theological position was irenic and it led to the development of Latitudinarianism in the seventeenth century. On this and related matters the near-definitive work is W.K. Jordan, The development of religious toleration in England, 3 vols. (London, 1938), especially vol. I. See also W. G. Zeeveld, The foundations of Tudor policy, (Cambridge, Mass., 1948). On Latitudinarianism, its links with constructive scepticism and its close relationship with the new philosophy, see B. J. Shapiro, John Wilkins, 1614-1672: an intellectual biography, (Berkeley and Los Angeles, 1969).


88. Thomas Hall, Vindiciae literarum ... /where/ cavils raised ... by Familists, Anabaptists Antinomians, Lutherans, Libertines, etc., are repelled and answered ..., (London, 1654), 199. 'Familiasticall' refers to an enthusiastic sect known as the 'Family of Love', see N. Cohn, op. cit., (note 81), 287-350; 'Levelling', of course, refers to the liberal political faction known disparagingly by their critics as Levellers. See P. Zagorin, A history of political thought in the English revolution, (London, 1954), 8-42.

89. See below, p. 221.

90. It is worth pointing out that Rattansi, op. cit., (87), mistakenly implies that Charleton was very close to enthusiasm when he published A ternary of paradoxes, (London, 1650) because he regards reason as a corrupt faculty, a 'dark Lanthorne', p. 26. However, Charleton does not speak of personal illumination from a Divine spark as the safest way to knowledge but recommends the much more prosaic way of faith in Scripture. In other words, Charleton already recognises that reason because of its dogmatism leads to danger and he is adopting the Hobbesian line, advocated in Leviathan of reliance on Scripture. See above Chapter 4, Section 1. Clearly Charleton is not yet aware of the method of constructive scepticism which Mersenne and Gassendi have developed as an improvement on simple fideism. Charleton and Hobbes were very close at this time, see Nina Rattner Gelbart, 'The intellectual development of Walter Charleton', Ambix, 18, (1971), 149-168; pp. 158-9. Needless to say as a royalist Charleton was very far from being of the 'Levelling temper'.

91. Walter Charleton, Physiologia, 6, 128. See also Immortality of the soul, 63-5 and 187-8; and Margaret Cavendish, Letters and poems in honour of the incomparable Princess Margaret, Duchess of Newcastle, (London, 1676), 111 and 112, where Charleton reiterates the importance of scepticism in a letter to the Duchess, May 7, 1667.

92. Physiologia, 479.

93. However, to the modern reader it is sometimes difficult to separate some of More's extravagant ideas from those which he condemned in his contemporaries. Consider, for example, some of his notions about the Jewish Cabbala conveniently outlined in B. P. Copenhaver, op. cit., (25), 515-29. For Alexandre Koyré, More belonged 'much
more to the history of the hemetic, or occultist, tradition than to that of philosophy proper' (op. cit., note 7, p. 125). Indeed even some contemporaries seem to have had such difficulties. The Somerset virtuoso, John Beale was very suspicious of Glanvill's *Lux orientalis*, (London, 1662), a work very close to More's way of thinking. Beale saw this as an 'extravagant adventure' and an exercise in 'Origenian Platonism' which should be suppressed (See his letter to Boyle, Oct. 31, 1666, Boyle, *Works*, (note 8), VI, 418). Boyle himself felt compelled to write a refutation of some of More's (and Cudworth's) ideas in his *Free inquiry into the vulgarly received notion of nature*, *Works*, V, 158-254. It seems more than likely that contemporary readers of Samuel Parker, *A free and impartial censure of the Platonick philosophie*, (Oxford, 1666) would see it as much an attack on Henry More and the Cambridge Platonists as it was against thinkers like John Heydon (fl. 1667) and Thomas Vaughan (1622-1666). Certainly, More himself was aware of this danger: 'I was afraid that men judging that this affectation of Platonisme in you [Vaughan], might well proceed from some intemperies of blood and spirit; and that... they might yoke me with so disordered a companion as yourself... ', (Henry More, *The second lash of Alazonomastix* laid on in mericie upon that stubborn youth Eugenius Philathes*, (London, 1651), 35-6. See F.B. Burnham, 'The More-Vaughan controversy: the revolt against philosophical enthusiasm', *Journal of the history of ideas*, 35, (1974), 33-49.


96. *Collection*, I, p. XV. This was written as late as 1662.


98. See Boyle's *Free inquiry into the vulgarly received notion of nature*, (note 93) and Robert Boyle, *An hydrostatical discourse, occasioned by the objections of the learned Dr Henry More, against some explications of new experiments ...* in *Works*, III, 596-628. See Greene, *op. cit.*, (7) and McGuire, *op. cit.*, (7).
99. See R. L. Colie, 'Spinoza and the early English Deists', Journal of the history of ideas, 20, (1959), 23-46; and idem, 'Spinoza in England, 1665-1730', Proceedings of the American Philosophical Society, 107, (1963), 183-219. I am using the word 'pantheism' slightly anachronistically as it was not coined until 1705 (by John Toland). Nevertheless, whether it was given the name or not, Boyle saw Spinozism as what would shortly be called Pantheism.

100. Boyle, Works (note 8), III, 628. This work first appeared in R. Boyle: Tracts ... containing new experiments touching the relation betwixt flame and the air ... etc., (London, 1672).

101. Ibid., 627.

102. For a further discussion of Boyle's 'constructive scepticism' see the following three notes and Chapter 6, Sections 1 and 2.


106. Laudan, op. cit., (103), 81-100. For an indication that Gassendi and possibly Charleton were the real influences on Boyle see Works, (note 8), II, 45.


108. Meric Casaubon, On learning, a previously unedited manuscript (1667) now published in M.R.G. Spiller,

R. H. Popkin, *op. cit.*, (note 4), 148. Cf. Royal Society, *Boyle Papers*, vol. XLIV, which are quoted in Laudan, *op. cit.*, (note 76), 82. While many scholars have considered the impact of Descartes on English thought (see note 2 above and 114 below), the impact of Gassendi has received scant attention (but for some beginnings see note 18 above). Little has been made, for example, of Gassendi's undeniable influence upon John Locke. See R. I. Aaron, *John Locke*, (Oxford, 1955), 9, 31-3, 35, 121, 156-7, 209 and 257.

111. See note 18 above.

112. See the article on More in *Dictionary of national biography*.


114. I have concentrated on Henry More here (as well as Charleton) because he played by far the biggest role in establishing Cartesianism in England. Ralph Cudworth, *op. cit.*, (note 25) is also important but by the time of its appearance the corpuscular philosophy and Cartesianism were already well established. It is important to remember, nevertheless, that More was not, alone among the Cambridge Platonists in showing an interest in Cartesianism. See J.B. Saveson, 'Descartes'

115. Although, as was pointed-out in the last chapter Hobbes was strongly influenced by Luther this does not mean he was a Puritan. Indeed, it was possible to be influenced by Calvin and still be an Anglican. See Nicholas Tyacke, 'Puritanism, Arminianism and counter-revolution', in Conrad Russell (ed.), The origins of the English Civil War, (London, 1973), 119-43.

116. One of the commonest means of attacking the Merton thesis is to show that the definition of 'Puritan' is too suspect to be of any value in establishing a valid historical thesis. See, for example, Michael Hunter, op. cit., (note 10), 113; and Lotte Mulligan, 'Puritans and English science: a critique of Webster', Isis, 71, (1980), 456-69; 458-62.

117. The exception to this is Christopher Hill, Intellectual origins of the English revolution, (Oxford, 1965). But this is problematic upon a number of other grounds. See the articles by H.P. Kearney and T.K. Rabb in Charles Webster (ed.), The intellectual revolution of the seventeenth century, (London, 1974), 218-42; 254-61; 262-79 and 284-5.


119. Ibid.

120. See above, Chapter 3, Section 5.


122. Alexandre Koyré, Galileo studies, (Hassocks, 1978),
p. 1: H.G. van Leeuwen, op. cit., (note 4), p. XIV and pp. 1-12. Although we have said that Laudan's paper on Cartesian hypotheticalism is fundamentally mistaken it is valuable for showing that Baconian influence on methodology has been exaggerated, L. Laudan, op. cit., (note 103). It would, of course, be going too far to say that Bacon had no influence but it must be recognised that the actual extent of his influence is very much a moot point. A recent paper has even cast doubt on the sincerity of Thomas Sprat's claims for the Baconianism of the Royal Society in his The history of the Royal Society of London, (London, 1667): P.B. Wood, 'Methodology and apologetics: Thomas Sprat's History of the Royal Society', British journal for the history of science, 13, (1980), 1-26. This whole area is ripe for careful reassessment but in the meantime see Michael Hunter, op. cit., (note 10), 8-21.


124. R. S. Westfall, 'Reflections on J.R. Ravetz's essay "Bernal's Marxist vision of history"', Isis, 72, (1981), 402-405; 404. Although the context of Westfall's remark is somewhat different from ours, the statement is equally applicable here. Westfall is attacking the Marxist interpretation of the history of science in general and so it can be applied specifically to Webster's similar interpretation of the scientific revolution.

125. A similar thesis has recently been proposed elsewhere: J. R. Jacob and M.C. Jacob, 'The Anglican origins of modern science: the metaphysical foundations of the Whig constitution', Isis, 71, (1980), 251-67. While there is a certain fundamental agreement between us, there are very many points in which I wish to differ from the Jacobs. I will return to this later (Chapters 6 and 7) but in the meantime I will state the main difference starkly: I believe that the 'metaphysical foundations' of the new natural philosophy were laid by Anglican thinkers from the earliest beginnings of the scientific revolution in England; the Jacobs, however,
believe that the major personnel involved in that revolution gradually changed their ideological position from Puritan to Latitudinarian to Anglican (pp. 258-9), a process of change which they describe as 'the dialectic of the Revolution itself', whatever that might mean (p. 252, 267). The quotation from Michael Hunter is from *op. cit.*, (10), 136.


127. *Collection, II*, 13 (my emphasis).

128. Ibid.


130. *Collection, II*, 31; see also p. 44. Although this position represents More's mature thinking, it should be pointed out that More, like Hobbes, seems to have passed through an earlier phase in which he believed in animated matter. Consider this passage from the letter to Descartes of July 23, 1649: 'I feel more disposed to believe that motion is not communicated, but that from the impulse of one body another body is so to speak roused into motion, like the mind to a thought on this or that occasion, and that the body does not take as much motion as it needs for movement, being reminded of the matter by the other body. And as I said a short while ago, motion bears the same relation to a body as a thought does to the mind: neither is received into the subject, in fact, but both arise from the subject in which they are found. And everything that is called body I hold to be alive in a sottish and drunken way, inasmuch as it is an image and the lowest and basest shadow, though destitute of sense and animadversion of the Divine essence, which I assert is the most perfect life ...'. Quoted from Gabbey, *op. cit.*, (2), 211; see also pp. 212-13. Gabbey even quotes the later 'Responsio and fragmentum Cartesii' (July/August 1655) in which animate matter is again invoked by More: 'But he *Descartes* is fabricating some kind of life in that when two bodies meet, he is able to
accomodate their motions so that each of them notified by the other, the one about acceleration of its motion, the other about retardation of its motion, finally agrees on the same course of motion. And it is the same thing for the other laws of transport. For Descartes himself scarcely dares to assert that the motion in one body passes into the other .... But since no motion passes from one body into another, it is manifest that one arouses the other from sleep as it were, and in this way aroused bodies transfer themselves from place to place by their own force; which property of bodies I consider as some shadow and image of life'.

131. Collection, I, 38.

132. Collection, I, 79-80. This is taken from More's second letter to Descartes. I have used the translation provided by E. A. Burtt, op. cit., (7), 131.

133. See above, Chapter 2, Section 2, Chapter 3, Section 6, and Chapter 4, Section 2.

134. Collection, I, p. XII.

135. Henry More, An antidote against atheism: or, an appeal to the natural faculties of the mind of man, whether there be not a God, (London, 1653); second edition, revised and enlarged (London, 1655).

136. Collection, I, 150.

137. Collection, I, 16.

138. Spirit was a form of substance for More: 'the precise Notion of Substance is the same in both Matter and Spirit', in which, I conceive, is comprised Extension and Activity either connate [in Spirit] or communicated [in Matter]. - Collection, II, 21.

139. Collection, I, 151.

140. Collection, I, 151-2.

141. Collection, II, 27.


143. Collection, II, 28.

145. See Greene, *op. cit.*, (7); Burnham, *op. cit.*, (93); and note 93 above.

146. But see note 130 above.

147. To deny God any active role in the world was to provide a hostage for atheists, but to make God too active was dangerously suggestive of the kind of pantheism which was then being advocated by various religious sects and by Spinoza. On pantheism in the sects see C. Hill, *op. cit.*, (80), 139-40, 142, 219, 394. On Spinoza see note 99 above. More was still accused of providing a footing for pantheists; see J. E. McGuire, *op. cit.*, (70) and note 98 above.

148. J. Glanvill, *op. cit.*, (24), 164.


151. *Collection*, I, pp. XV-XVI.

152. *Collection*, I, 44. See also I, pp. XV-XVI.


154. *Collection*, II, 11. More was presumably defending himself here against attacks like this one from Robert Hooke: '... if all things be done by an Hylarchic Spirit, that is, I know not what, & to be found I know not when or where, and acts all things I know not how, what should I trouble myself to enquire into that which is never to be understood, and is beyond the reach of my Faculties to comprehend? Whereas on the other side, if I understand or am informed that these Phenomena do proceed from the quantity of matter and motion,
and that the regulating and ordering of them is clearly within the power and reach of man's Industry and Invention; I have encouragement to be stirring and active in this inquiry and scrutiny, as where I have to do with matter and motion that fall under the reach of my senses ....'. See Robert Hooke, Lamps, or descriptions of some mechanical improvements of lamps and water poises with other physical and mechanical discoveries ... in R. T. Gunther (ed.), Early science in Oxford, 14 vols. (Oxford, 1921-45), VIII, 188. Hooke indulges here in a lengthy critique of More's Enchiridium metaphysicum, see pp. 182-95.


156. See for examples: Collection, I, 43-4, 46, 93; and II, 12, 196-9.


158. On essential spissitude see Collection, II, 20 and Joseph Glanvill, op. cit., (24), 169-70. Although More's concept of essential spissitude has been noticed, no-one, as far as I know, has understood why More invoked it. See for example Burtt, op. cit., (7), 129-30 and Koyré, op. cit., (7), 129-30. Interestingly Koyrè tries to understand More's concept by drawing an analogy with the varying intensity of light.

159. See note 126 above and Kargon, op. cit., (18), 83, 85, 86.

160. Collection, II, 193-96, and notes 156 and 158 above.

161. See note 130 above.

162. Charles Webster, op. cit., (65), 393.


164. Ibid., 149-50, 151, 154, 160, 163, 167-8.

165. Charlton's earliest works were all heavily indebted to Van Helmont but Van Helmont himself was not unaffected by the burgeoning mechanical philosophy. Indeed, the foremost scholar of Van Helmont's work, Walter Pagel, has recently argued that Van Helmont identified his chemical philosophy with the mechanical philosophy. Walter Pagel, Joan Baptista van Helmont, reformer of science and medicine, (Cambridge, 1982), p. 27.
166. Rattansi, *op. cit.*, (87). Anyone with a thorough knowledge of the background of seventeenth-century intellectual life should have been immediately alerted to the unlikelihood of Charleton's radicalism on seeing that Alexander Ross (1591-1659) wrote a eulogistic poem for Charleton's *Ternary of paradoxes* (see next note). Ross is surely one of the least radical writers of those times, whether in religion, philosophy, or politics. He wrote a refutation of the Copernican hypothesis as late as 1647: *The new planet no planet*, (London, 1647), and not only opposed Digby and Hobbes in print but even Sir Thomas Browne: *Arcana microcosmi, or the hid secrets of man's body; with a refutation of Dr Browne's Vulgar Errors*, (London, 1651). Furthermore, Ross was always a staunch Anglican, being appointed as Chaplain to Charles I by Laud's influence sometime before 1622. Ross' association with Charleton at the very beginning of the younger man's writing career provides further circumstantial evidence for my contention that Charleton was always Anglican in his religious ideology.

167. J.B. Van Helmont, *A ternary of paradoxes; the magnetical cure of wounds, the nativity of tartar in wine, the image of God in man, translated, illustrated and amplified by Walter Charleton*, (London, 1650). Charleton did publish a work prior to this in the same year but it is a derivative medical treatise and contains nothing of philosophical interest: *Spiritus gorgonicus vi sua saxi para exutus; sive de causis signis et sanatione lithiaeos diatriba*, (Leyden, 1650).


169. Van Helmont, *Ternary*, D4r and C3r; see also C3v and D3r.

170. B.J.T. Dobbs, 'Studies in the natural philosophy of Sir Kenelm Digby', *Ambix*, 18, (1971), 1-25; p. 6. Gelbart, *op. cit.*, (90) does not recognise the full extent of Digby's influence on Charleton because she believes that Digby did not write about the powder of sympathy until '1657' (this should read '1658') in his *Late discourse made in a solemn assembly of nobles and learned men at Montpellier in France ... touching the cure of wounds by the powder of sympathy ...*, (London, 1658). However, Digby had already explained the action of the powder in the *Treatise on body*, (Paris, 1644), pp. 164-5.
notes pp. 223 - 227

173. Charleton, *Darknes*, a1r, 158. See also pp. 4, 40, 41-3.
174. *Darknes*, 44.
175. *Darknes*, 46.
176. *Ibid*.
181. I have omitted Robert Boyle from the discussion so far on the grounds that, although he was active during the Interregnum, his major influence was not felt until he began to publish during the Restoration period.
183. On Digby and White see above Chapter 3, Section 6. On Hobbes see Chapter 4, Section 2. There are even clear traces of the residual influence of light metaphysics upon Charleton's *Physiologia*. Chapter II of Book III argues 'That species visible are substantial emanations', pp. 136-148. Section 20 combines Charleton's own idea of spontaneous motion of atoms with the Digbean idea that atoms are driven off by the impact of light particles: 'The Facility of the Abduction or Avolation of Images Visible from solid concretions solved by the Spontaneous Exsiliation of their superficial Atoms: and the Solicitation of light indicient upon them', pp. 144-5. In Chapter V, 'The nature of light', pp. 198-207, he distinguishes between primary light (*lux*) and secondary light (*lumen*), p. 199. He also insists that light is material (pp. 204-206), that its motion takes a finite amount of time (p. 206) and that it is always in motion (p. 200-1).
184. See above Chapter 4, Section 2.
NOTES TO CHAPTER 6


2. J R Jacob has written most extensively on Robert Boyle and we will consider his ideas on Boyle below. However, he believes that the ideology of Boyle and of the Royal Society 'merged' into one and so we can regard many of his pronouncements on Boyle to be applicable to the Royal Society. See J R Jacob, 'The ideological origins of Robert Boyle's natural philosophy', *Journal of European Studies*, 2 (1972), 1-21; *idem*, 'Restoration, Reformation and the origins of the Royal Society', *History of science*, 13 (1975), 155-76; *idem*, *Robert Boyle and the English Revolution: a study in social and intellectual change* (New York, 1977); *idem*, 'Boyle's atomism and the Restoration assault on Pagan naturalism', *Social Studies of Science*, 8 (1978), 211-33; and J R Jacob and M C Jacob, 'The Anglican origins of modern science: the metaphysical foundations of the Whig Constitution', *Isis*, 71 (1980), 251-67


5. Jacob, Boyle and Revolution (note 2), p 133.


10. M Hunter, op. cit. (8), 140-3.


12. For example, although Oldenburg wished Wren to undertake the redesigning of London after the great Fire as though it were a Royal Society project, Wren was appointed to the task as an individual and the Society played no role. See Hunter, op. cit. (8), 90.

13. See above. M Hunter, op. cit. (8), also includes an account of the general failure of Royal Society utilitarian schemes, pp. 87-112.

historical analysis of 'Worldly asceticism' is, of course, Max Weber, *The Protestant ethic and the spirit of capitalism* (London, 1976). Weber shows how the asceticism of Protestant theology can lead to the acquisition of wealth and other worldly pursuits. I admit that Weber's arguments are extremely plausible but they may still be said to rely upon special pleading. It would seem that a much fuller analysis of seventeenth-century Protestant attitudes is required.


17. J R and M C Jacob, 'Anglican origins' (note 2), p. 251; and J R Jacob, 'Boyle's atomism' (note 2).


21. M Hunter, op. cit. (8), 38-41; and P B Wood, op. cit. (20). Note also that Sprat himself points out the apologetic nature of his book: '... Objections and Cavils against it [the Society], did make it necessary for me to write of it, not altogether in the way of a plain History, but sometimes of an Apology'. (Sig. B4v.)
22. Jacob has taken Sprat's History at its face value and treats it as an authoritative statement of the Society's aims. He has failed to notice Webster's criticisms of this view in his 'Origins of the Royal Society' (note 20).


24. It may be objected that, nevertheless, Moray did not supervise Sprat's History but Wilkins did. This does not show a unified outlook by all the members of the Society, however. What it does show is that the prominent scientists among the small group of founder members did, by and large, share the same outlook, as represented by Wilkins.

25. See Chapter 5, Section 1.

26. Sprat rejects the philosophy of 'the Chymists', for example, Because 'they are downright Enthusiasts'. Sprat, op. cit. (19), p.37.


30. On this see Webster, op. cit. (20), 114, 125; and Wood, op. cit. (20), 8-10. If further evidence of the mitigated scepticism of the Society is required, consider Robert Hooke's words in his dedication of Micrographia to the Royal Society. Hooke says: 'The Rules You have prescrib'd YOUR selves in YOUR Philosophical Progress do seem the best that have ever yet been practis'd... particularly that of avoiding Dogmatizing...' (See note 109 below for reference, sig. A2v.). See also Joseph Glanvill's dedication of Scepsis scientifica to the Royal Society: J Glanvill, Scepsis scientifica: or, confess ignorance the way to science... (London, 1665). For a full discussion of the various ways in which Baconian philosophy of science was translated into practice see P B Wood, 'Francis Bacon and the "experimental philosophy": a study in seventeenth-century methodology' (M Phil thesis, University of London, 1978).
31. J R Jacob, *Robert Boyle and the English Revolution* (note 2), p.159. Personally, I do not think we can grant this last point anyway. The historical continuity of the development of science and its autonomy as an epistemological system militate against such a view.


34. This would surely be the only outcome of 'men of disagreeing parties, and ways of life /who/ have forgotten to hate, and have met in the unanimous advancement of the same Works'. (Sprat, *op. cit.* (19), p. 427.). Such disparate members could hardly agree sufficiently to bring about Jacob's 'Reformation of the World' (note 5 above).

35. J R Jacob, 'Ideological origins' (Note 2), 1-2.

36. I say, 'like the Blackloists and Henry More' because we have seen that they were engaged upon the pursuit of natural philosophy for ideological purposes. Jacob, however, has completely overlooked these earlier English developments. Furthermore, he seems to be unaware of the similar enterprise of Mersenne in his early works (before he developed with Gassendi a more sceptical position). Jacob seems to regard his own interpretation of Boyle's endeavours as revealing a unique and original aspect of seventeenth-century mechanical philosophy. On the Blackloists see Chapter 3 above. On More, see Chapter 5.

37. Chapter 5, Section 1.


40. Boyle, Works, II, 45
41. Ibid., I, 355-6.
43. Published anonymously at London in 1675 it appears in Boyle's Works, IV, 151-91, see p.165.
46. On this see J M Batten, John Drury, advocate of Christian reunion (Chicago, 1944). Drury was a leading member of the Hartlib circle.
47. [R Boyle], Reasons why a Protestant should not turn Papist: or, Protestant prejudices against the Roman Catholic religion (London, 1687).
48. The belief that the soul was immortal by its very nature was a comparatively recent dogma of the Catholic Church. It seems to have been made part of official Church doctrine at the Lateran Council of 1513. On this, see N T Burns, Christian mortalism from Tyndale to Milton (Cambridge, Mass., 1972).
50. Boyle, Works, IV, 12.
51. Ibid., 13.
52. Ibid., 13.
53. Jacob, Boyle and Revolution (note 2), 133.
54. R Boyle, Some considerations touching the usefulness of experimental naturall philosophy... (Oxford, 1663); idem, The Christian virtuoso: showing that by being addicted to experimental
philosophy, a man is rather assisted, than indisposed to be a good Christian (London, 1690). See also, idem, A disquisition about the final causes of natural things: wherein it is inquir'd, whether, and (if at all) with what cautions, a naturalist should admit them? (London, 1688).

55. See, for example, The Christian virtuoso (previous note), and Some considerations about the reconcileableness of reason and religion (London, 1675); Reflections upon a theological distinction that represents some things as above reason, but not contrary to reason (London, 1690).

56. For example. The usefulness of natural philosophy (note 54): Some occasional thoughts about the excellency and grounds of the mechanical hypothesis (London, 1674); and A discourse about the possibility of the Resurrection (London, 1675).


58. Chapter 5, Section 1.


60. Ibid., 434. I do not agree entirely with Dr Boas Hall on this distinction. The ancient atomists did use the motion of atoms as an explanatory device, as well as their shapes and sizes. As I have said in Chapter 1, I believe the emphasis on 'matter in motion' among seventeenth-century thinkers to stem from their philosophical distaste for both concepts in the ancient maxim: 'atoms and the void'.
66. See for example, *ibid.*, p. 23-4. It may be that Boyle has in mind sympathetic resonance as a case of local motions transmitted 'at a distance'. See below p. 269.
68. *Ibid.*, 445, also 447. There is an earlier recognition of the Epicurean explanation as having equal credibility as the Cartesian in the first edition of the *Physiological essays* (1661), *Works, I*, 387. The later *Essay of languid and unheed motion* (note 64) also contains 'An historical account of a strangely self moving liquor', *Works, V*, 71-3, which may well have been presented as an 'experimental proof' that there may be self-moving bodies.
69. *Works, I*, 457. See also p.444 where Boyle says he 'durst not affirm' that there are bodies at rest and 'inclined to the negative'.
70. See above, Chapter 5, Section 2.
71. M Boas Hall, *op. cit.* (59), 475-7; 475.
74. Perhaps it really was haste which caused Boyle to leave this problem as a doubt but he never slowed down long enough to answer the problem.
75. Works, V, 615.

76. Ibid. See also refs. in note 73, especially Works, I, 179-80.

77. I am tempted to be more dogmatic but the evidence remains somewhat elusive. I have already hinted that the account of a 'self-moving liquor' is meant to provide an experiential proof of such innate activity (note 68) and I also believe that Boyle's efforts to demonstrate the long duration of the Spring of the air has similar intentions. In New observations about the duration of the spring of expanded air (1671), Works, III, 501-4, Boyle wonders 'whether it [air] would not at length come not to have a weaker spring, but perhaps to have no sensible spring at all, as we see it happen in sword-blades and divers, other springy bodies, which, after having stood too long bent, will continue so, and lose their former power of self-restitution'. After experimentation Boyle concludes that 'for all the long stretch' he subjected air to it did 'not lose anything of its spring' (pp. 502-3). It seems to me that Boyle is hinting here that elasticity in air is not due to spring-like structure in the particles - which would weaken like that of sword blades - but is due to motion which remains undiminished because it is innate. However, Boyle does not draw this out so my interpretation must remain speculative.

78. The letter, which appears in Works, V, 638-45, is undated and I have been unable to find the original (or a copy) in either the collection of Hartlib manuscripts at Sheffield University Library or the vast amount of Boyle manuscripts at the Royal Society. It is conceivable that Boyle wrote the letter between 1660 and 1670 - the suggested year of Hartlib's death. However, I know of no other evidence that Boyle kept up his acquaintance with Hartlib after 1660. It seems most likely, therefore, that he wrote this letter during the Interregnum.

79. The History appears in Works, V, 609-750. The publisher's preface tells us that the collection was authorised for publication by Boyle himself, p. 610.
80. The only other place I have seen this work mentioned is L Thorndike, _A history of magic and experimental science_, 8 vols. (New York, 1958), VIII, 186-7. Even this only makes a passing reference to the work.

81. Works, V, 638.

82. Ibid., 638-9.

83. Ibid., 639; see also 642.

84. The observations Boyle has in mind are of 'all lunatic, epileptic, paralytic, or lethargic persons', p. 639.

85. Boyle is evidently speaking in terms of individual objects here not the corpuscular parts of such objects. The generation or corruption of an individual is not simply a movement of that individual but a beginning or an end to the possibility of that individual moving. The corpuscles, however, are merely moving in the ordinary sense.

86. Works, V, 639.

87. Ibid., 640.

88. Ibid.

89. It should be noticed that Boyle is speculating so wildly as to fall into contradiction. A moment ago condensation-rarefaction was regarded as a first principle into which physical phenomena may be resolved. Now, moisture, heat, etc. are said to produce these principles. We will see Hooke make similar metaphysical contradictions, below, Section 3.

90. The text reads 'and' instead of 'or' - evidently a printer's error.

91. Works, V, 640.

92. Works, IV, 85-96; 90.

93. The _Aerial noctiluca: or some new phaenomena, and a process of a factitious self-shining substance_ (London, 1680), Works, IV, 379-405; 384.

94. Works, V, 641.
95. Ibid. This equation between soul or spirit and light is also a familiar theme in light metaphysics. Indeed, we have already seen Henry More drawing on the same aspect of the tradition, above, Chapter 5, Section 2.

96. This reference, linking magnetism with the nature of a planet must be inspired by a knowledge of William Gilbert's work in establishing the Earth as a giant magnet. We will return to Gilbert later in this chapter, below, Section 4.

97. Works, V, 641.

98. Ibid., 642.

99. Ibid., 641, 644.

100. Ibid., 642.

101. It is also possible that Boyle's acquaintance with Newton made him less inhibited about discussing the possibility of active principles. See following chapter.


103. This is the heading given to Boyle's letter to Hartlib in The general history of the air, Works, V, 638.


105. Ibid.


108. Marie Boas Hall, op. cit. (59), 417, 422.

109 R Hooke, Micrographia: or some physiological descriptions of minute bodies made by magnifying glasses with observations and enquiries thereupon (London, 1665), 11-12. Hooke did publish one other brief work before this: An attempt for the explication of the phaenomena, observable in an experiment published by the Honourable Robert Boyle, Esq... (London, 1661). Hooke still awaits the scholarly attention he deserves but there are
two books which go some way to assessing his life and achievements: Margaret 'Espinasse, Robert Hooke (London, 1956); and F F Centore, Robert Hooke's contributions to mechanics: a study in seventeenth-century natural philosophy (The Hague, 1970).

110. Hooke, Micrographia, 12.

111. Ibid., 15; see also 85.

112. It must be pointed out, however, that Hooke's mechanical account of sympathetic resonance is inadequate. As Henry More pointed out in The immortality of the soul (London, 1659) mechanists 'before they attempted to show the reason, why that String that is not Unison to that which is stuck should not leap and move, as it doth that is, they should have demonstrated, that by the mere Vibration of the Aire, that which is Unison can be so moved; for if it could, these Vibrations would not faile to move other Bodies more movable by farre then the String it self that is thus moved'. (A Collection of several philosophical writings, 2 vols. (London, 1662), II, 193).

113. Hooke, Micrographia, 16.

114. Ibid., 15. See also p. 21 where congruity is casually referred as a 'property of cohesion', and p. 32 where it becomes an 'attractive virtue'.

115. Ibid., 27-8.

116. Ibid., 28.

117. Ibid.

118. Hooke's own sceptical, undogmatic approach is made explicit in the Preface to Micrographia, especially sig. alr-blv. But see also his General scheme or idea of the present state of natural philosophy, and how its defects may be remedied by a methodical proceeding in the making experiments and collecting observations. Whereby to compile a natural history, as the solid basis for the superstructure of true philosophy. This
appears in R Hooke, The posthumous works, edited by Richard Waller (London, 1705), 1-70. This requires a full study in its own right as an important document in the methodology of the scientific revolution. For indications of scepticism see pp. 3-7, 8-12.

119. This phrase is usually applied by theologians to the soul. Cf. Henry More's similar ideas, above Chapter 5, Section 2, and Hooke's Posthumous works, 146.

120. Hooke, Posthumous works, 79. The closing words of this quotation are rather reminiscent of Boyle's ideas on astrology, above p. 259-61. Hooke's lectures on light dating from the early 1680s appear in the Posthumous works, pp. 71-148 and 193-200.

121. Ibid., 90.

122. Ibid., 96.

123. Ibid., 97.

124. For example, Posthumous works, 79, 92-3, 114-5.

125. Posthumous works, 130-1; Micrographia 54-6. See also below p. 278-9. It should be noticed that the view of light as material or a shock in the medium are also inconsistent with each other.

126. 'Read at the meetings of the Royal Society, soon after Michaelmas 1682.' Posthumous works 149-190 and 191.

127. Ibid., 166.

128. Ibid., 172.

129. Ibid., 175.

130. Ibid., 174.

131. Ibid., 175; see also 179. See Chapter 2, Section 2 for similar ideas in earlier thinkers.

132. Gravity always seems to be conceived as an innate property of matter while light is
sometimes innate but at other times (e.g., p. 97) is an active principle external to matter.

133. Marie Boas Hall, *op. cit.* (59) believes, mistakenly, that Hooke's aether is Cartesian, p. 454. Alexandre Koyre, *Newtonian Studies* (London, 1965) refers to it as the cause of gravity which is also a misreading, p. 184 but see note 136 below. F. F. Centore, *op. cit.* (109) discusses it in the context of various scientific problems—such as planetary motion and transmission of light—but does little to establish its metaphysical significance.


136. This in itself makes it totally different from the Cartesian 'aether' which does send out radial pulses as a result of the centrifugal tendency of the circulating particles in the vortices. Having said this, however, there is one place where the aether is said to play an active role in gravity. In *Micrographia*, Hooke supposes the aether to be an all-pervasive yet universally incongruous fluid which, on account of its incongruity, will 'endeavour to detrude all earthly bodies as far from it as it can; and partly thereby, and partly by other of its properties may move them towards the Center of the Earth'. (p. 22). Even this version of the aether can hardly be said to be Cartesian—however, it could be said to be an active principle (or rather its incongruity could).


138. I say 'usually' because of his observations referred to in note 124 above. On the infinite velocity of light see *Posthumous Works*, 79, where Hooke rejects Roemer's arguments for the finite speed of light; 99-100; and 130.

139. See above p. 271-3 and p. 274-6. The use of vibration as a quasi-metaphysical concept was extremely important in Hooke's speculative natural philosophy and, I believe, lies at the root of his extensive scientific investigations of vibrations in springs, strings, and pendulums. On which see, Louise D. Patterson, *Pendulums*

One of Hooke's favourite examples, which he believed could only support his hypothesis, was the luminescence of a diamond that has been vigorously rubbed. The light cannot be caused by a stream of matter given off because the diamond would waste away. He rejects the Hobbesian notion of small circular motions of the parts (see above, Chapter 4, Section 2) on the grounds that the diamond could not then hold together. The parts of the diamond cannot be whirling in a vortex and giving off light according to the Cartesian account, so the parts must be making short swift vibratory motions. See Micrographia, 55-6.

140. Hooke, Posthumous works, 184. Ironically, Hooke not only accounts for light in a way which Hobbes had earlier rejected, see above Chapter 4, Section 2, but he also misunderstands Hobbes's later theory of light propagation. He rejects an account which is closer to the Cartesian explanation as though it were a refutation of Hobbes. He mistakenly assumes that Hobbes's account of light relies not on any real motion but only a conatus or tendency to motion. Although this is true of Descartes it is not true of Hobbes. See Posthumous works, 130-1, and compare with our account of Hobbes's theory above, Chapter 4, Section 2.

141. Posthumous works 185. There are eighteen lines 'Of magnetism' on p. 192.

142. Ibid., 119, 123.

143. Ibid., 185, see also 183-4 for a different example of the same phenomenon.

144. Ibid., 184.

145. There are other aspects of Hooke's theory of the aether which detract from its intelligibility. Unlike the Cartesian aether, Hooke's version seems to have contradictory properties. On the one hand Hooke claimed 'that the Aether has very little, if any, Impe'ding Power to the motion of solid Bodies through it' (Ibid., P. 170); while on the other he insisted that it must be 'perfectly Dense; that is,
such as will not be by any Power forced into less Dimensions than it is contained in, but does completely fill and maintain that space' (p. 113). This contradiction must be regarded as damaging because intelligibility was a sine qua non for the mechanical philosophy. See, for example, Robert Boyle, Works, I, 355.

146. Rarefaction provides a convenient extra example of Hooke's inability to arrive at a firm conclusion about a common phenomenon. In the Micrographia he talks of an aether incongruous to all matter in spite of pervading all matter. Its incongruity causes it to 'detrude' all matter from it, see note 136 above. In De potentia restitutiva (London, 1678), however, he explains it in terms of the motions of the particles: 'all fluid bodies whatsoever would... have their parts fly from each other were it not for some prevailing Heterogenous motion from without them that drives them more powerfully together'. This is reprinted in R T Gunther (ed.), Early science in Oxford, 14 vols (Oxford, 1923-44), VIII.


148. (London, 1674). The discourse was read to the Society on November 26, 1674.

149. See Kargon, op. cit. (147), 65-6.

150. See above p.24-6 and Chapter 5, Section 2.

151. Petty, Discourse, 4.

152. Ibid., 17, 18. On Charleton see above, Chapter 5, Section 3.

153. Ibid., 18; see also 125-6.

154. Ibid., 127, 128.

155. Ibid., 128-30.

156. I have said above (Section 1) that it is a mistake to exaggerate the unanimity of the
Royal Society. Nevertheless, the small core of founder members who met at Interregnum Oxford can be regarded to be of one mind on most scientific issues. The leading light of this group was John Wilkins but William Petty also played a big role. On this Oxford group see M Purver, op. cit (20), 101-27,; and R G Frank, Harvey and the Oxford physiologists: scientific ideas and social interaction (Berkeley and Los Angeles 1980), especially 51-89. On Wilkins see B J Shapiro, John Wilkins 1614-72: an intellectual biography (Berkeley and Los Angeles, 1969).

157. F R Johnson, Astronomical thought in Renaissance England: a study of English scientific writings from 1500 to 1645 (Baltimore, 1937), 216-20 231.42. But see also note 177 below.

158. The only scholars I have come across who are aware of this aspect of Gilbert's work are A Koyré, From the closed world to the infinite universe (Baltimore, 1957), 55-7; E A Burtt, The metaphysical foundations of modern physical science: a historical and critical essay (London, 1932), 157; and J A Bennett, 'Hooke and Wren and the system of the world: some points towards an historical account', British journal for the history of science, 8 (1975), 32-61, 36-7, 40.

159. Foremost among these studies is E Zilsel, 'The origins of William Gilbert's scientific method', Journal of the history of ideas, 2 (1941), 1-32. But see also D H D Roller, 'Did Bacon know Gilbert's De magnete?' Isis, 44 (1953), 10-13; and Marie Boas Hall, 'Bacon and Gilbert', Journal of the history of ideas, 12 (1951), 466-7. Even Mary Hesse in her survey 'Gilbert and the historians', British journal for the philosophy of science, 11 (1960), 1-10, 130-42, makes no mention of Gilbert's endeavour to establish the motion of the earth.


162. Ibid., 23-4

163. Ibid., 64-71; 64.

164. Ibid., 66.

165. Ibid., 66-8.

166. Ibid., 68.

167. Mary Hesse, op. cit. (159), 138, 139. See De magnete, 74-115 and 304-12.

168. Gilbert refers to an Earth soul throughout but see especially De magnete, 308-12.

169. Ibid., 105.

170. Ibid., 322, also 323.

171. Ibid., 328.

172. Ibid., 326, also 327, and 333 where we are told that the Earth rotates 'by a certain law of necessity...'. By the way, while talking 'of the potency of the magnetic force', Gilbert compares the energy of magnetism with that of light, p. 123-4. The impelling power of the sun and light is evoked again pp. 330-3 and Gilbert concludes that the 'causes of the Earth's diurnal revolution' are 'partly by the energy of the magnetic property and partly by the superiority of the Sun and his light' p.347.

173. I have used the fifth edition: John Wilkins, A discovery of a new World, or, a discourse tending to prove, that tis probable there may be another habitable world in the Moon with a discourse concerning the probability of a passage thither. Unto which is added, a discourse concerning a new planet tending to prove, that tis probable our Earth is one of the planets (London, 1684), 115-6.

174. Ibid., 118-9, 120-2.

175. The quotation comes from Wren's inaugural lecture as professor of astronomy at Gresham College in 1657. It is reprinted in: Christopher Wren, Parentalia: or, memoirs
Actually Petty is going rather too far here because while Gilbert established, to his own satisfaction, that the Earth rotated on its axis he could not find an argument for its revolution about the Sun. It was Kepler who tried to extend Gilbert's ideas to account for the planetary revolutions. On this see: A Koyre, *The astronomical revolution: Copernicus, Kepler, Borelli* (Paris, London and New York, 1973), 197-214. I believe the only reason Gilbert did not argue in a similar manner to Kepler was the fact that he could not demonstrate such a circulatory motion by means of experiments with *terrellae*. The whole point of Gilbert's experimental method was to establish that although magnets operated by invisible, insensible means they could not be said to operate in an occult manner. On the contrary Gilbert believed that the so-called 'occult and hidden cause' of magnetism could be 'brought to light and demonstrated' by experiments (p. 229) so that in the end magnetism could be said to be 'a cause that is manifest, sensible, and comprehended by all men' (p. 328). By showing the motions of his *terrellae* in experiments he could conclude justifiably that the Earth moved in the same way. However, it was only the Earth's diurnal rotation which came within the scope of this methodology. Indeed, even here, it must be said, Gilbert did not fully achieve all he could have wished for. As is well known, Gilbert could not repeat the experiment of Petrus Peregrinus (fl. 1269) in which a *terrella* made a complete rotation in twenty-four hours (p. 332. See also John Wilkins, *op. cit.* (173), p. 120-1). It was partly to circumvent this problem that he introduced the impulsive power of the Sun and its light into his system (see note 172 above). I return to this aspect of seventeenth-century methodology below, and an important paper has just appeared which backs-up my own


179. Ibid., 126-7.

180. As far as I know, nobody has noticed the influence of Gilbert upon Petty before. Certainly R H Kargon, op. cit (147), makes no mention of it. If there should be any doubt in the reader's mind perhaps I should point to one other aspect of Petty's *Hypothesis* with echoes of Gilbert. Seemingly a propos of nothing Petty interjects: 'Lastly, I might suppose (even without a Metaphor) that Atoms are also Male and Female, and the Active and Susceptive Principles of all things; and that the above-named Byasses are the Points of Coition: For that Male and Female extend further than to Animals, is plain enough'... (p. 130-1). Once again this odd notion has clear antecedents in *De magnete*, Gilbert refers to magnets as male and female (p. 23) and rejects the concept of 'attraction' in favour of 'coition' (pp 74-97).


182. See above p. 283-4, and note 180.


184. A virtuoso member of the Royal Society, Sir Robert Southwell, is a little more explicit than Petty in a 'Discourse concerning water' which he read to the Society on April 8 1675. Adopting Petty's hypothesis Southwell believes that the properties of water may be explained quite easily: 'I humbly conceive, that the atoms, whereof water is made, are globes or globular; that their polar motions are but faint; that the motions of their biases one towards another are a little, but not much, stronger; and the tendencies of them towards the center of the Earth, or specific gravity is not great'. See Thomas Birch, *The history of the Royal Society of London, for improving of natural knowledge, from its first rise...* 4 vols. (London, 1757), III, 196-216; 197. I owe this reference to
Mr Stephen Pumfrey.


187. *Ibid.*, 3-4. The implication of this is that the mechanical philosophy can no longer be characterised in terms only of contact action between particles. The criterion now is to explain things in terms of common phenomena whose real existence cannot be denied and which can be demonstrated by experimental means. This enterprise lay at the heart of Gilbert's work on magnetism (see note 177) and has also been recognised in the work of Robert Hooke and Christopher Wren. See J A Bennett, *op. cit.* (158), 44-7.

188. *Philosophical transactions*, no 16 (August 6 1666), 282. I have taken this reference from J A Bennett, *op. cit.* (158), 47.


190. See above p. 253-5.


192. Though it seems likely that Edward Stillingfleet would have done (see above p. 226 ), and Thomas Barlow certainly did. See Thomas Barlow, *The genuine remains of that learned Prelate...* ed. P Pett (London, 1693), 155-59 and above p. 112-3.

193. I have interpreted these developments as an essentially new approach to methodology, but Keith Hutchison, *op. cit.* (177), having a completely different perspective has traced similar attitudes at least as far back as Sennert. Rather than seeing this as a new approach, Dr Hutchison argues that historians have misunderstood the import of 'occult qualities' in its seventeenth-century usage. In spite of superficial differences, I think we are essentially in agreement.
NOTES FOR CHAPTER 7


3. It is generally assumed that Newton hoped to provide a rigorous mathematical analysis of his inter-particulate forces as he had done for the gravitational force. Of course there was no thought of this among the earlier thinkers.


5. It would not have been applicable to Hobbes's ideas after 1655 (the year of publication of *De corpore*) but it would have been applicable to his earlier ideas in the 1630s. See Chapter 2. Keill's statement is also applicable to Digby, Charleton and More. See Chapters 3 and 5.


7. Thackray, Atoms and powers (6) admits this, p. 32. There are some indications in the literature of earlier influences but for the most part they begin with Newton and look forward in time. Exceptions are J E McGuire, 'The origins of Newton's doctrine of essential qualities', Centaurus, 12 (1968), 233-60; and John L Russell, 'Action and reaction before Newton', British journal for the history of science, 9 (1976), 25-38; both of which, incidentally, single-out the influence of Digby and the latter also of Thomas White on Newton. The major work on a closely related topic is R S Westfall, Force in Newton's physics (London, 1971) but this deals mostly with the role of force in Newton's mathematical physics or the development of dynamics as a science. It says little about force as an active metaphysical principle which is our focus here (see above, in the Introduction). For general indications of influences on Newton see A R Hall, 'Sir Isaac Newton's note-book, 1661-1665', Cambridge historical journal, 9 (1948), 239-50; R S Westfall, 'The foundations of Newton's philosophy of nature', British journal for the history of science, 1 (1962), 171-82; Henry Guerlac, 'Newton et Epicure',

8. The quoted phrase is from Steven Shapin, 'History of science and its sociological reconstructions', History of science, 20 (1982), 157-211; p. 175.


18. *Opticks* (12), 403-4. Newton's philosophy of science here does not differ significantly from that of Cardinal Bellarmine and Pope Urban VIII when they admonished Galileo not to come to any dogmatic conclusions about the structure and organisation of the universe. See Georgio de Santillana, *The crime of Galileo* (Chicago, 1955) especially pp. 98-102 and 165-67. This similarity of outlook provides further confirmation that Newton, like Bellarmine and the Pope, was concerned to protect religion from attack by those who would misuse an irrefutable fact.


20. The fundamental sources for a study of Newton's voluntarism are the *Letters to Bentley* (11) and H G Alexander (ed.), *The Leibniz-Clarke correspondence* (Manchester, 1956). For discussions of this important topic see: E A Burtt, *The metaphysical foundations of modern physical science* (London, 1924), 280-99; A Koyré,
notes pp. 303 - 304


22. These features of Newton's attitude to his work are always recounted in his biographies. See, for example, Frank E Manuel, A portrait of Isaac Newton (Cambridge, Mass., 1968) and R S Westfall, Never at rest: a biography of Isaac Newton (Cambridge, 1980). For his caution with regard to pronouncements on matter theory in particular see Hall and Hall, Unpublished scientific papers (6), 184-213.

23. Opticks (12), 339-406. The publishing history of the 'Queries' is complex. The first sixteen appeared in the first edition of 1704. A further seven were added to the first Latin edition in 1706. For the second English edition another eight were interpolated as Queries 17-24 making Queries 17-23 of the Latin edition into Queries 25-31 of this edition. The eight queries which made up the latest addition were all concerned with aether speculations. For an account of slight variations in the queries of different editions see J E McGuire, 'Force, active principles' (6).
notes pp. 304 - 306


25. On this famous dictum see A Koyré, op. cit. (6), 25-52 and 261-72; and I B Cohen, op. cit. (6), 575-89.

26. See below pp. 320-1.

27. See above, Chapter 6, Section 4.


31. My own researches have tended to confirm the judgement of Barbara Shapiro that 'one of the most striking patterns to emerge from an examination of the thought of seventeenth-century English and Continental scientists, whatever their particular religious commitments, is an almost universal suspicion of religious disputes, accompanied by a pronounced desire for religious compromise and unity', Shapiro, op. cit. (29), 224. The clearest indication of the Latitudinarian and scientific opposition
to atheism and deism is the foundation of the Boyle Lectureship. On this see M C Jacob, The Newtonians (10), 143-200, and John J Dahm, 'Science and apologetics in the early Boyle Lectures', Church history, 39 (1970), 172-86. Although the rubric of the Boyle Lectures specifically excluded discussion of sectarian disputes within Christianity - 'not descending lower to any Controversies that are among Christians themselves' - this does not mean they were not concerned to settle such disputes. It simply means that they recognised that any attempt to debate such disputes in public would be entirely counter-productive. Indeed, it is worth remembering that the arguments of the Boyle Lecturers against deism were also dangerously counter-productive. Benjamin Franklin (1706-1790) actually claimed that he was converted to deism by his reading of some of the Boyle Lectures. See Benjamin Franklin, Autobiography and other pieces, ed. by Dennis Welland (London, 1970), p. 53. On what I refer to here as the 'phenomenalist' methodology of science see above, Chapter 6, Section 4.


36. I do not wish to imply that science is a completely autonomous discipline. On the contrary, I strongly believe that scientific developments are shaped by psychological, religious and social determinants. It seems to me that to deny this is an absurd and untenable position. However, it is equally absurd to try to show a direct correspondence between the details of a natural philosophical system and the transient, and parochial concerns of every-day politics. It is one thing to show, as I have done, that Digby and White's natural philosophy is linked to a broad political desire for freedom of worship for Catholics, but it is quite another to show that matter theory is linked to the party politics of Court-Whigs. See Chapter 3 above.

37. M C Jacob, _The Newtonians_ (10), 84, see also 73-5, 80.

38. _Ibid._, 74.


40. _Ibid._, 72, 82-3. Margaret Jacob's misrepresentation of apocalyptic beliefs as millenarian concerns is another example of her determination to reduce things to political interests at all costs. See above, Chapter 3, Section 5.

41. _Ibid._, 228.

42. The plausibility of her case is only really established in a recent article by C B Wilde, 'Matter and spirit as natural symbols in eighteenth-century British natural philosophy, _British Journal for the History of Science_, 15 (1982), 99-131. By using the sociolinguistic theories of Basil Bernstein and the anthropological theories of Mary Douglas, Wilde has at least been able to show how political and social structures might influence & determine the whole of an individual's deeply held beliefs. I do not wish to pursue Wilde's analysis here. It would require a detailed exposition of Mary Douglas's views on natural symbols and their role in systems of belief. Moreover,
Wilde himself admits that his own conclusions are 'sketchy' and only 'suggestive' (p. 129).


45. It is well-known that Newton admonished Bentley for speaking as though gravity was 'essential and inherent to matter'. See *Letters to Bentley* (11), 20, 25. See also A Koyré, *Newtonian Studies* (6), 149-63. Leibniz also attributed this view to Newton in his *Theodiceé* (Amsterdam, 1710), 27. See I B Cohen, 'Newton's copy of Leibniz's *Theodicée* with some remarks on the turned-down pages of books in Newton's library', *Isis*, 73 (1982), 410-414; p.411. The Newtonian William Derham also believed gravity to be inherent to matter, see W Derham, *Physicotheology, or a Demonstration of the Being and Attributes of God* (London, 1786), 42 note n and 45.


47. Shapin, *op. cit.* (10), 188.

48. Ibid., 192. I believe Shapin has to confine himself to vague statements like this because any stronger statements would be seen to be untenable. However, this is a little too vague. It almost implies that a voluntarist and a necessitarian theologian would disagree about the validity of the Ten Commandments - a set of ethical prescriptions if ever there was one.
49. See my comments in Chapter 3, Section 5 above.

50. Shapin, op. cit. (10), 201.

51. Ibid., 213.

52. On this see Frank E Manuel, The religion of Isaac Newton (Oxford, 1974) and David Castillejo, op. cit. (6), 57-75; and Westfall, Never at rest (22), 312-34. For a general treatment see Eamon Duffy, 'Primitive Christianity revived: religious renewal in Augustan England', Studies in Church history, 14 (1977), 287-300.

53. Larry Stewart, op. cit. (10).

54. William Whiston, Sermons and essays upon several subjects (London, 1709) see pp. 123, 412; Samuel Clarke, The Scripture doctrine of the Trinity (London, 1712). See also, Thomas Herne, An account of all the considerable books and pamphlets that have been wrote on either side in the controversy concerning the Trinity... (London, 1720). For Newton's influence on the heterodoxy of Whiston and Clarke see Westfall, Never at rest (22), 649-53.

55. Larry Stewart, op. cit. (10), 68.

56. Ibid., 69.

57. M C Jacob, Newtonians (10), 205. It is my contention that the very point which Margaret Jacob makes here was fully recognised at the time and had been recognised ever since the turbulent days of the Interregnum. It was just this which led to the cautious, undogmatic stance which has been called 'constructive scepticism'.

58. Although Newton and his fellow voluntarists believed that their theology guaranteed the existence of God, necessitarians believed that these same ideas led to pantheism. For the necessitarians, only an omnipotent and transcendant God was incapable of such a heretical interpretation. Voluntarists, however, believed that the necessitarian God was so transcendant that he might not even exist! For an outline of the ideas of a
group of English necessitarians consider
A J Kuhn, 'Glory or gravity: Hutchinson
vs. Newton', Journal of the history of
ideas, 22 (1961), 303-22; and C B Wilde,
'Hutchinsonianism, natural philosophy and
religious controversy in eighteenth-century
Britain', History of science, 16 (1980),
1-24.

59. For a further corrective to these views see
Geoffrey Holmes, 'Science, reason and religion
in the age of Newton', British journal for the

60. See Chapter 1 above.

61. See Chapter 2, 3, 5 and 6 above. More and
Charleton stand representative of those who
repudiated strict mechanism on religious
grounds, while Boyle and Hooke seem to have
been faced by insuperable 'scientific'
obstacles.

62. Westall, 'Foundations' (7), 180. For further
discussion of this note-book see A R Hall,
'Sir Isaac Newton's note-book, 1661-65',
(note 7).

63. This is now included in Hall and Hall,
Unpublished papers (6), 214-20, translated
221-28; see p. 214 (Latin) and 221 (English).
I have relied on the Halls' translation
throughout.

64. Ibid., 223.

65. See above, Chapter 5, Section 2.

66. Hall and Hall, op. cit. (6), 224.

67. Ibid., 227. There is a valuable discussion of
Newton's use of the aether in their introduction
But see also their, 'Newton and the theory
of matter' in R Palter (ed.), The annum
mirabilis of Sir Isaac Newton, 1666-1966
(Cambridge, Mass., 1970), 54-68; H Guerlac,
'Newton's optical aether', Notes and records
of the Royal Society, 22 (1967), 45-57; and
idem, 'Francis Hauksbee, experimentateur au
profit de Newton', Archives internationales
68. Isaac Newton, 'An hypothesis explaining the properties of light, discoursed of in my several papers', read at the Royal Society, 1675/6; published in Thomas Birch, _The history of the Royal Society of London_ (London, 1757), III, 247-60. Now reprinted in I B Cohen (ed.), _Papers and letters_ (11), 178-90. I will refer to Cohen's edition but will provide the page number in Birch in parentheses. Newton made his reluctance to provide this hypothesis in a brief prefatory epistle, p. 178 (248).

69. Ibid., 179 (249).

70. This letter, dated January 25, 1676/7, was first published in Robert Boyle, _The works_, 5 vols. (London, 1744), I, 74, and is reprinted in Cohen (ed.), _Papers and letters_ (11), 254. It is worth pointing out that much of Newton's aether speculations in the _Hypothesis of light_ and this letter to Oldenburg can only be understood as deriving from Newton's alchemical studies. I do not wish to pursue the chemical traditions of active matter in this thesis (see Introduction, above) but see J E McGuire, 'Transmutation and immutability: Newton's doctrine of physical qualities', _Ambix_, 14 (1967), 84-6; and R S Westfall, 'Newton and the Hermetic tradition' in A G Debus (ed.), _Science, medicine and society in the Renaissance_, (New York, 1972), 183 98; pp. 189-90. The chemical background to the _Hypothesis of light_ is perhaps most obvious when Newton introduces the non-mechanical concepts of 'sociable' and 'unsociable' matter, Cohen (ed.), _Papers and letters_ (11), 183 (253).


73. Hall and Hall, *op. cit.* (6), 189-90. This is a very important point. The Halls' perceptive analysis may be supplemented with Alexandre Koyré, 'Newton's' regulae philosophandi' in *idem, Newtonian studies* (6), 261-72; and J E McGuire, 'Atoms and the "analogy of nature": Newton's rules of philosophizing', *Studies in history and philosophy of science*, 1 (1970), 3-58. See also K Hutchison, *op. cit.* (28), 250-53; and above, Chapter 6, Section 4.

74. See above note 67.


77. Hall and Hall, *op. cit.* (6), 317 (Latin at 314).

78. *Ibid.*, 303. The Halls translate this as 'Lattice structures' p. 306, but 'net-like textures' or even 'net-like webs' is more literal.


83. Sir Kenelm Digby, *Two treatises, In the one of which the nature of bodies: In the other the nature of mans soule is looked into: in way of the discovery of the immortality of reasonable soules* (Paris, 1644), 21. See above, Chapter 1, Section 3.
84. For the influence of Digby upon Newton see, for example, Westfall, 'Foundations' (7), 172; J E McGuire, 'The origin of Newton's doctrine of essential qualities' (note 7), pp. 244-6, 250-1; and John L Russell, 'Action and reaction before Newton', OP cit (7).

85. Hall and Hall, OP cit. (6), 184; see also p. 201 where Newton is even said to be 'muddled' in his thinking.

86. Opticks (12), 339. It should be remembered that Newton's decision to couch his speculations in query form was not simply a result of contingent limitations upon his work, but also reflects a cautious sceptical methodology as discussed in Section 1.

87. See the works cited in note 6 above and G Bowles, 'John Harris and the powers of matter', Ambix, 22 (1975), 21-38.

88. Although Newton tried to deny that gravity was an innate power in matter he was not so cautious when dealing with interparticulate forces. See, for example, Opticks (12), 375-6.

89. These and other thinkers are the dramatis personae in the various works cited in note 6. Faraday only appears in Heimann and McGuire, 'Newtonian forces', 305-6.

90. C B Wilde, 'Hutchinsonianism' (58); G Cantor, 'The historiography of 'Georgian optics', History of science; 16 (1978), 1-21; and Simon Schaffer, 'Natural philosophy' in G S Rousseau and Roy Porter (eds.), The ferment of knowledge: studies in the historiography of eighteenth-century science (Cambridge, 1980), 55-91. Schaffer cites one or two other critics of this monolithic, exclusively Newtonian, genealogy, p. 57 note 8.

91. Thackray, Atoms and powers (6), 32; Heimann, 'Nature is a perpetual worker' (6), 9. Similarly, J E McGuire has said that the development of Newton's concept of force 'cannot be explained adequately in terms of Newton's mathematical approach to physical phenomena as found in his early and pre-Principia (1687) manuscripts. Nor can it be explained by analyzing Newton's work in
relation to the physics of Galileo, Descartes, or Huyghens' - 'Neoplatonism and active principles' (7), 95.

92. This has already been done for Hermann Boerhaave. There has been a tendency to see Boerhaave as a follower of Newton since Helene Metzger's *Newton, Stahl, Boerhaave* (6); consider, for example, Heimann, 'Nature is a perpetual worker' (6). But an excellent article has traced Boerhaave's concept of fire, his active principle, to pre-Newtonian chemical and neo-Platonic authors: Rosaleen Love, 'Some sources of Herman Boerhaave's concept of fire', *Ambix*, 19 (1972), 157-74.

93. Reprinted in Hall and Hall, *op. cit.* (6), 89-121, translated 121-56. The Halls suggest that this was written between 1664 and 1668 and certainly not later than 1672, p. 90.


96. For the influence of Patrizi upon Newton's concept of space see Markus Fierz, 'Über den Ursprung und Bedeutung der Lehre Newtons vom absolutem Raum', *Gesnerus*, 11 (1954), 62-106; and John Henry, 'Francesco Patrizi da Cherso's concept of space and its later influence', *Annals of Science*, 36 (1979), 549-75. On Patrizi's emanationist metaphysics see Benjamin Brickman, *An introduction to Francesco Patrizi's 'Nova de universis philosophia'* (New York, 1941); and E E Maechling, 'Light metaphysics in the natural philosophy of Francesco Patrizi da Cherso,' (M Phil thesis, University of London, 1977). Newton's concept of space as described in the early *De gravitatione* (93) is especially close to Patrizi's concept, not only in its relationship to God and the physical universe but also in so far as both men declare it to be neither substance nor accident but a special category of being. See Hall and Hall, *op. cit.* (6), 131-2 and Patrizi *Nova de universis philosophia* (Venice, 1593), f65r. Moreover, like Patrizi, Newton defines body in terms of its resistance to penetration or hardness. Hall and Hall, pp. 139-40, Patrizi, *op. cit.*, f62v.

98. This manuscript is now at the Smithsonian Institution, Washington D C, and is part of the Burndy Collection: Burndy MS.16.

99. Burndy MS.16, f.3v-4r.

100. Westfall, Never at rest (22), 305, 307.

101. I have deliberately excluded chemical concepts from my coverage. See the Introduction above. On the alchemical foundations of the Hypothesis of light, however, see note 70 above.

102. I admit that, in a sense, the alchemical notions and the emanationist ideas cannot be entirely divorced in so far as they both derive from neo-Platonic traditions. Nevertheless, I believe there is a discernible break after Newton says: 'Hitherto I have been contemplating the nature of aether... now I come to join therewith the consideration of light'. (Cohen, op. cit., note 11, p. 184). After this the chemical imagery gives way to more physical conceptions.

103. Cohen (ed.), op. cit. (11), 184 (254) and 179 (249).

104. Ibid., 184-5 (254-5).

105. Ibid., 185 (255).

106. Ibid., 188 (258).

107. Ibid., 188 (258) and 180 (250).

108. I suggested earlier (Chapter 4, Section 3) that Descartes regarded his theory of light as a crucial factor in his ability to describe 'le monde' and I am now suggesting that Newton can be seen as part of a tradition deriving from that insight.
into the usefulness of theories of light for the mechanical philosophy. The existence of such a tradition has been pointed-out in A C Crombie, *Robert Grosseteste and the origins of experimental science, 1100-1700* (Oxford, 1953), pp. 277-89, and developed throughout this thesis.


112. See above, Chapter 3, Section 7, and Chapter 4, Section 2. Newton was not consistent about this, however. In Query 31 he denies the perpetual activity of the Sun and argues that its energy must be recruited from time to time either by God or 'the active Principle' which causes the Sun to shine. See *Opticks*, 399. For an account of this aspect of Newton's thought see D Kubrin, *op. cit.* (20).

113. Heimann, 'Nature is a perpetual worker' (6), 15; Wilde, 'Hutchinsonianism' (58), 13.

115. For example: John Hutchinson, *Moses's Principia. Being an account of the natural agents which perform the operations of nature, viz. The Air, or Fire, Light, and Spirit*, in *The philosophical and theological works*, third edition, 12 vols. (London, 1748–9), II, especially pp. 175-99, 207-21, 356-66, 420-7. See also *Moses's Sine Principio: or, the meaning of the Names and Titles of God... in Works*, III, 207-14 where an analogy is drawn between Christ, the Son, and the Sun; Herman Boerhaave, *Elements of chemistry*, trans by T Dallowe (London, 1735); Hutton, *op. cit.* (114); George Berkeley, *Siris: a chain of philosophical reflexions and inquiries concerning the virtues of tar-water, and divers other subjects* (London, 1744); Joseph Priestley, *The history and present state of discoveries relating to vision, light and colours*, 2 vols. (London, 1772), II, 786-91; Herschel, *op. cit.* (114). Less well-known writers in this category include: Gowin Knight, *An attempt to demonstrate that all the phaenomena in nature may be explained by two simple active principles, attraction and repulsion* (London, 1754); Cadwallader Colden, *The principles of action in matter, the gravitation of bodies and the motion of planets explained from those principles* (London, 1750); Harrington, *op. cit.* (114); and Higgins, *op. cit.* (114). These and other writers are discussed in one or other of the following studies: Metzger, *Newton, Stahl, Boerhaave: Thackray, Atoms and powers*; Schofield, *Mechanism and materialism*; Heimann and McGuire, *'Newtonian forces'*; Heimann, *'Nature is a perpetual worker'* all fully cited in note 6 above; Love, *op. cit.* (92); Wilde, *'Hutchinsonianism'* (58); and Schaffer, *'Great laboratories'* (114); and *idem*, *'Natural philosophy'* (90).

116. See above, Chapter 2, Section 2.

117. *Newton, Opticks* (12), 405.

118. I do not wish to imply that either Warner or Hobbes were direct influences on Newton. I merely point out that the traditions of light metaphysics had a continuous vitality from the very beginnings of the mechanical philosophy to its culmination in the work of Newton and, as we have seen, beyond.
NOTES TO CONCLUSION

1. Other aspects of the topic, not covered here, are referred to in the Introduction.


3. As indeed they still do. After all, we still cannot explain gravitational attraction or the nature of the other fundamental forces.

4. On this see Chapter 6, Section 4 above and K Hutchison, 'What happened to occult qualities in the Scientific Revolution?', *Isis*, 73 (1982), 233-53. For an example of observation over a long period of time in order to demonstrate the possibility of incessant motion in matter see R Boyle, *An historical account of a strangely self-moving liquor*, in *Works*, 6 vols. (London, 1772), V, 71-3, which is discussed in Chapter 5, Section 2 above.


9. I am in agreement, therefore, with M Purver, *The Royal Society: concept and creation* (London, 1967), 158; and M Hunter, *Science and society in Restoration England* (Cambridge, 1981), 116. I am not denying the theistic aspects of the natural philosophy of Boyle, Charleton, Newton and others. However, I do believe that these aspects of their philosophy were couched only in the broadest terms to prove the existence of God. There is little or nothing in their theism which could be seen to be specific to a particular kind of religion. Their arguments are completely non-sectarian. Margaret Jacob has admitted that 'in the hands of the unorthodox almost any philosophical system could be made ungodly', op. cit. (8), p.205. It is my belief that this simple fact was so obvious that it was widely recognised in Restoration England. It is for just this reason that men like Boyle did not try to oppose one ideologically inspired version of the mechanical philosophy with another. Any effort along those lines would be bound to be counter productive. The only safe alternative was to adopt a cautious sceptical stance.

10. The principal example of the argument that science was developed in order to bolster the Whig constitution is J R and M C Jacob, 'The Anglican origins of modern science: the metaphysical foundations of the Whig constitution', *Isis*, 71 (1980), 251-67. Science as an epiphenomenon of the growth of capitalism has been recently stated in Carolyn Merchant, *The death of nature, women, ecology and the Scientific Revolution* (San Francisco, 1980). Part of Dr Merchant's thesis is that the growth of modern science was what would be called today an anti-feminist movement. For another example of this science-as-anti-feminist thesis see Brian Easlea, *Witchhunting, magic and the new philosophy: an introduction to debates of the Scientific Revolution, 1450-1750* (Hassocks, 1980).

11. For example, I drew attention to a similarity between the theories of Hobbes and Hooke in Chapter 6, Section 3 and to similarities
between the theories of Power and Toland in Chapter 1, Section 4.

12. This is the main theme of their paper on 'The Anglican origins of modern science' (note 10). Carolyn Merchant, op. cit. (10) also argues that 'Because nature was now viewed as a system of dead, inert particles moved by external rather than inherent forces, the mechanical framework itself could legitimate the manipulation of nature. Moreover, as a conceptual framework, the mechanical order had associated with it a framework of values based on power, fully compatible with the directions taken by commercial capitalism', p. 193.

13. A corollary of Margaret Jacob's thesis would seem to be that had England become 'a Republic of pantheists' after the 'Glorious Revolution' we would now be studying John Toland's physics in our schools. See M C Jacob, op. cit. (8), p. 249.

14. Our own times have seen the way scientific progress can be seriously impeded by being bent to suit some political purpose or another. Consider the abuses of Lysenkoism or of right-wing efforts to prove the innate mental inferiority of women and negros.

15. For the fullest discussion of the major themes of the tradition see Chapter 2.

16. The importance of a nexus of common assumptions for the development of science has recently been given full consideration in R G Frank, Harvey and the Oxford physiologists: scientific ideas and social interaction (Berkeley, 1980). I believe that this thesis provides further evidence of such implicit preconceptions in seventeenth-century thinkers. Indeed, as we saw in the last chapter (Chapter 7), the belief in light as a form of active principle lasted well into the eighteenth century also.

17. A C Crombie, Robert Grosseteste and the origins of experimental science, 1100-1700 (Oxford, 1953). It is worth pointing out that Dr Crombie's conclusion also asserts the non-dogmatic nature of the experimental method (pp. 315-19). Moreover, he points out
that such a method cannot be used to support interpretations 'of theology or ethics' and, we might add, of politics (p. 319).

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