ABSTRACT

Today, Petty is most widely remembered as a founder of modern economics. Thus his brilliant analysis of the labour theory of valve, the role of monopolies, the velocity of circulation and other like concepts helped guide the development of classic economic thought over the ensuing centuries. His second substantial achievement, at least in the popular mind, depends on the outstanding success of the Down Survey, the first in English history to be organised along scientific lines, utilising the principle of the division of labour. Beyond this, details of his life and his other intellectual pursuits have attracted only marginal interest. His extraordinary career, prolific writing on education, technology, medicine and society and his relationship with the broad intellectual movements of the day have often seemed mere curiosities. At best they have been regarded as peripheral adjuncts to that select group of theories which guarantee his status among more orthodox historians.

The thesis shows that such judgements are narrow, misleading and unhistorical. Petty's more celebrated ideas become intelligible only when their evolution and context receive detailed attention. This process would itself be misleading if wider historical considerations were excluded. Pre-eminent among such issues is the remarkable efflorescence of natural philosophy between 1640 and 1680. These chronological points loosely denote an outstanding period of growth with which Petty was intimately concerned. When closely scrutinised, the relationship between this figure and his environment emerges as one of complex cause and effect. Only by attracting and encouraging two or three remarkable generations could English natural philosophy gain momentum. In its turn the training of these recruits gave them the motivation and capacity to devise fresh modes of enquiry. It is a paradox of history that, while this movement's dynamic was shortlived, it thereafter survived and eventually grew into a radical force that changed man's understanding of society and the natural world. The main purpose of this work is to describe Petty's experience of this revolution in ideas.

Another significant aspect is the light which is cast on current historiographical debate. While it hopefully avoids slavish discussion of such issues, the thesis has been written with these more immediate concerns in mind. For example Petty's utilitarianism , his debt to 'continental' and 'puritan' science, his view of the Royal Society, his role in pre-Restoration natural philosophy, his method and his scientific originality are all examined so as to illuminate contingent historical problems. While not rejecting other modes of research it would seem that Petty's intellectual biography provides an ideal case for testing some general interpretations with the litmus of the particular. The results indicate a more complex picture than many historians have hitherto protrayed.

This approach has necessarily dictated the shape of the present monograph. In consequence its detailed biographical account acts as a preface for three chapters of specialised intellectual analysis. Re-examination of Petty's early life, using fresh manuscript sources, has produced a wealth of information that fully documents his experience during these vital years. The later achievements and failures are shown to be products of this training which, while not a determinant of fortune, helped him profit from those dynamic situations for which he instinctively sought. Petty's well-known ideas are shown as natural, if not inevitable, consequences of this background and they are joined by others which warrant greater attention and acclaim. Overall, the first chapter gives a new and integrated account of his career stressing its continuity and debt to English and Continental natural philosophy.

Chapter two presents a brief analysis of Petty's views on economic improvement, education, medicine and technology. This is linked with his early acceptance of Bacon and is shown to be part of a contemporary genre which called for economic renewal, enhanced productivity and social regeneration. Perhaps at his most 'puritan', if not pietistic, over these issues, Petty regarded them as integral parts of a broad plan for social reform. Correct education was essential for every child. Without popular training in applied science and mathematics, self-sustaining technologies capable of fuelling economic improvement would not spontaneously develop throughout the country.

Co-equal with educational reform came the provision of medical facilities for the whole population. Petty saw the need for painstaking research into nosological, aetiological and nutritional factors. Since the value of a skilled worker was already substantial and since this would increase as the economy became more sophisticated, it was in the nation's best interest to keep him healthy. With this as the cutting edge of his medical views, Petty also expressed genuine concern for his fellow man. The most important point was that humanitarianism was also a practical necessity. Research into disease would only progress through empirical means, and universal health care was the sole means of providing a sufficient number of cases from which to gather data. This research would be carried out in a new type of teaching hospital which Petty described with meticulous care. In addition, the national requirement for doctors would be controlled by the government to ensure a rational distribution of skills throughout the realm. Petty therefore believed that a medical policy based on sound statistics, monitored by the government and supported by effective clinical treatment would eradicate the worst effects of epidemics and malnutrition.

The last constituent of his general policy called for systematic development of new machines and techniques. Throughout his life Petty tried to encourage invention for reasons of personal profit and social gain. Brief attention is paid to two of his unsuccessful projects: double-writing and the twin-hulled ship. In each case Petty proved himself an original and determined innovator. His comparative failure provides an excellent example of those factors which restricted invention and discouraged the spread of new technology during this period.

Chapter three illustrates the link between Petty's career, his belief in improvement and reform and his response to important elements in contemporary natural philosophy. By analysing the genesis and structure of his Discourse of Duplicate Proportion an unusually detailed picture of one seventeenth century work is also obtained. This essay was a synoptic, but unpolished statement of Petty's approach to science and philosophy. Occasioned by an institutional crisis it became a vehicle for defending the Royal Society against vehement criticism. In showing that its research was both scientific and useful, Petty hoped to quell the Society's misguided opponents. The result was an idiosyncratic blend of applied mathematics, utilitarianism, Galilean mechanics and atomistic philosophy. Petty's defensive and didactic purpose limited the work's scope in 1674 but now provides the reader with an unparalleled insight into his later attitudes. It also gives an appropriate introduction to his econometric and statistical exercises.

The final chapter investigates Petty's empiricism and his mathematical approach to economic and demographic theory. This does not minimise those few outstanding theoretical achievements which have already received widespread acclaim from modern historians. Instead it explores other ideas which were of

equal importance to Petty's methodology. By establishing that this was a product of his 'Baconian' philosophy, practical experience and more abstract analytical approach (ultimately derived from Cartesian and continental models) a more judicious assessment of Petty's socio-economic thought is reached. This exposes his careless extrapolation from unreliable data, but shows that such errors were consonant with his deep understanding of the need for accurate social and economic surveys.

Fresh evidence proves that Petty tried time and again to gain government support for a national bureau of statistics and that when these efforts failed he gathered statistical information from every available source. Further evidence shows that he understood how to use this data to reorganise vital elements within the English economy. As always, his projects were constructed with great care and attention to detail. Although at variance with the prevailing political climate they were, without doubt, both farsighted and inherently practical.

Given the inevitable limitations of a thesis and the elusiveness of historical evidence, various issues covered by this Chapter have received only limited attention. For example, the perplexing relationship between Petty and Graunt has been examined, but the central problem of authorship remains unsolved. Fresh analysis of this question confirms the current view that both men published their ideas as joint and original contributions to the new discipline of socio-economic analysis. Unfortunately, a definitive reconstruction of their individual roles must await the discovery of manuscripts which may no longer exist.

By the end of the enquiry Petty emerges as a leading figure of seventeenth century natural philosophy. The breadth of his interests, his outstanding insight into social, technological, economic and institutional problems and an indomitable, if occasionally unrealistic, drive to implement his ideas guarantee him a place at the side of Boyle, Newton and Ray. Even his failures show that he possessed unusual creativity and vision. Petty's remarkable career and his personal synthesis of scientific ideas also confound modern attempts to categorise the 'Scientific Revolution' under any particular causal, religious or terminological heading. Only by looking at him as an individual within the context of a larger movement can the pluralism of both emerge. Finally, we are left with the irony that as a social and scientific prophet Petty was rejected by most of his contemporaries while, three centuries later, his methods and ideas have been vindicated one after the other.

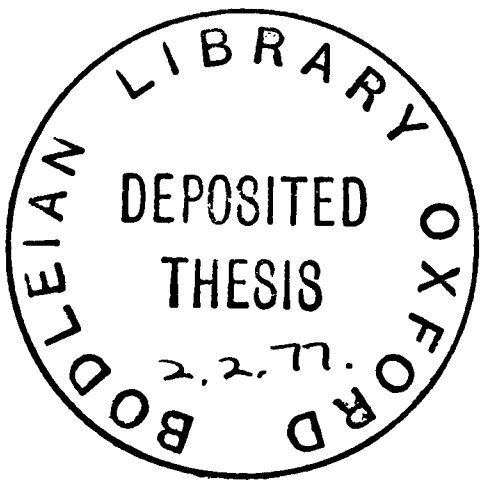
SIR WILLIAM PETTY AND SOME ASPECTS OF SEVENTEENTH CENTURY NATURAL PHILOSOPHY

D.PHIL. THESIS

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ABBREVIATIONS

The following abbreviations are used in the Notes:

Aubrey, Brief Lives.	J.Aubrey, Brief Lives, ed. A.Clark, 2 vols. (Oxford, 1898).
Bacon, Works.	Sir F.Bacon, The Philosophical Works of Francis Bacon, Reprinted from the Texts and Translations, with the Notes and Prefaces, of Ellis and Spedding, ed. J.M.Robertson (London, 1905).
Birch, History.	T.Birch, The History of the Royal Society of London For Improving of Natural Knowledge from its First Rise, 4 vols. (London, 1756-57).
Boyle, Works. (1744 ed.)	The Works of the Honourable Robert Boyle, ed. T.Birch, 5 vols. (London, 1744).
Boyle, Works. (1772 ed.)	The Works of the Honourable Robert Boyle, ed. T.Birch, 6 vols. (London, 1772).
D.N.B.	Dictionary of National Biography.
Fitzmaurice, Life.	Lord E.Fitzmaurice, The Life of Sir William Petty 1623-1687 (London, 1895)
Hartlib, Ephemerides.	Samuel Hartlib, 'Ephemerides', Hartlib Papers, Sheffield University Library, Professor Turnbull's typed copy.
Hill, Intellectual Origins.	C.Hill, Intellectual Origins of the English Revolution (Oxford, 1966).
Hull, Economic Works.	Sir W.Petty, The Economic Writings of Sir William Petty Together with Observations Upon The Bills of Mortality More Probably by Captain John Graunt, ed. C.H.Hull, 2 vols, (Cornell, n.d., reprinted Kelly, New York, 1963).
Jones, Ancients and Moderns.	R.F.Jones, Ancients and Moderns. A Study of the Rise of the Scientific Movement in Seventeenth Century England (Los Angeles, sec. ed. 1961).
Keynes, Bibliography.	G.Keynes, A Bibliography of Sir William Petty, F.R.S. And Of Observations on the Bills of Mortality by John Graunt F.R.S. (Oxford, Clarendon Press, 1971).
Lansdowne, Petty Papers.	The Petty Papers. Some unpublished writings of Sir William Petty, ed. Marquis of Lansdowne, 2 vols. (London, 1927).

Lansdowne, P.S.C.	Marquis of Lansdowne, The Petty-Southwell Correspondence 1676-1687 Edited from the Bowood Papers (London, 1928).
Pepys, Diary.	S.Pepys, The Diary of Samuel Pepys, ed. R. Latham and W. Matthews, 9 vols. (London, 1970-).
Philosophical Transactions.	Philosophical Transactions of the Royal Society of London. The Roman numeral indicates the issue number, which is followed by its publication date and pagination. This convention is adopted because contemporary binding of the journal was often erratic.
Strauss, Sir William Petty.	E. Strauss, Sir William Petty Portrait of a Genius (London, 1954).
Turnbull, H.D.C.	G.H. Turnbull, Hartlib, Dury and Comenius, Gleanings from Hartlib's Papers (London, 1947).
Webster, Advancement.	C. Webster, Samuel Hartlib and the Advancement of Learning (Cambridge, 1970).
Webster, Instauration.	C. Webster, The Great Instauration Science Medicine and Reform 1626-1660 (London, 1975
Wood, Athenae Oxonienses.	A. Wood, Athenae Oxonienses, ed. P. Bliss, 4 vols. (Oxford, 1813-20).

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This study resulted from the author's interest in seventeenth-century natural philosophy, originating in the undergraduate subject 'The Scientific Movement in the Seventeenth Century'. Throughout my research innumerable people have helped by discussion, or by the provision of material, and I would like to express my deep gratitude to them here. In particular, I wish to thank the Marquis of Lansdowne, and Lord Shelburne, for their great kindness in allowing access to the Papers at Bowood House, and for providing such elegant surroundings in which to work. I also owe an enormous debt to Charles Webster, my supervisor, who originally suggested Petty as an interesting subject and was so generous with his time throughout the ensuing five years. In addition, I would like to thank Dr. T.Barnard, Dr. R.L-W. Caudill, Mrs. S.MacKnight, Miss A.Lawrence, A.J.Turner, R.A.G.Pearson, Dr. D.Fairer and M.G.Caldwell for their help, Mrs. Irene Ashton and my wife, Maggie, for their great patience in typing, and my parents for their abundant liberality.

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INTRODUCTION

Sir William Petty's life presents immediate problems for any biographer who wishes to confine his analysis to a specific part (though a central one) of his interests and activities. In the case of the present work, an examination of his achievements in, and his profound experience of, seventeenth century natural philosophy inevitably calls for a detailed treatment of his early intellectual development and the cultural influences which moulded his career. As a result of this particular concentration, certain areas of his life, both in historical and personal terms, can only be viewed in a general way.

Some major events and attachments of Petty's career will therefore receive only passing attention: his work as one of the most important administrators of the Cromwellian regime in Ireland, his complex legal dealings over Irish possessions, the evolution of his multifarious business ventures, his general relationship with political and courtly life after the Restoration, and his fascinating, though turbulent, personal experiences. These aspects of his life will be explored only in so far as they elucidate the development of his views on natural philosophy, and indeed they have been covered adequately by other biographical and historical works. In particular, the biographies of Strauss and Fitzmaurice, the collected edition of his economic tracts by Hull,[1] and the bibliography by Keynes, provide a broad picture of his activities and ideas, allowing the present work to concentrate on natural philosophy as

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1. E.Strauss: Sir William Petty, Portrait of a Genius, (London, 1954); Lord Edmond Fitzmaurice: The Life of Sir William Petty, 1623-1687, (London, 1895); C.H.Hull: The Economic Writings of Sir William Petty, (Cambridge, 1899, reprinted New York, 1963); G.L.Keynes, Kt: A Bibliography of Sir William Petty, F.R.S., (Oxford, 1971). For Fitzmaurice's biography see Keynes, Bibliography, p.42. For Hull's original edition see ibid, p.65.

the essential, unifying (and hitherto unexplored) aspect of Petty's career.

Owing to his enormous mental vigour, wide cultural experience, and outstanding virtuosity, it is impossible to investigate closely each intellectual environment encountered by Petty or each development influenced by him. Such an account would necessarily require a complete description of cultural life in England, Ireland, and the continent, for most of the Seventeenth Century. Reference will be made to a number of general works which have described specific areas of this broader intellectual and historical context; in particular, Charles Webster's publications give an excellent, detailed account of the relevant English and continental developments between 1600 and 1660.[1] Works which present broad contextual information include Dr. Barnard's recent book, and the unpublished dissertation of Dr. Frank.[2] Naturally, the present study differs from such accounts over innumerable points of detail and interpretation, especially where the progress of Petty's natural philosophy is concerned. However, I wish at this point to make a full acknowledgment of the assistance provided by these and other works.

Beyond this it is hoped that justification for the approach adopted by this study will emerge as the argument progresses. Earlier, specialised attempts to analyse Petty's life and works have often been valuable, but have dealt in isolation with particular exploits and ideas. Petty has, for example, received the attention of authors who were primarily

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1. C.Webster: The Great Instauration, Science, Medicine and Reform, 1626-1660, (London, 1975). The present author would like to express his gratitude to Mr. Webster who generously allowed him access to the manuscript of this work. Assessment of this major contribution is given in, H.R.Trevor-Roper, 'The Age of Projects'. The Listener (12 February 1976), 186-187; C.Hill 'Scientists of the Republic' New Statesman (14 November, 1975), 613-614; K.V.Thomas 'Agents for Utopia' The Guardian (27 November, 1975); Q.Skinner 'Projectors and Practitioners' T.L.S. (2 July, 1976) 810-812.
2. T.C.Barnard, Cromwellian Ireland, English government and reform in Ireland, 1649-1660 (Oxf. hist. monogr., London, 1975). R.G.Frank, 'Oxford and the Harveian Tradition in the Seventeenth Century' (Harvard Univ., Ph.D. thesis 1971).

concerned with his importance as one of the great early English economists,[1] as a comical designer of unworkable naval vessels,[2] as a brilliant cartographer[3] and as a typical Baconian of late seventeenth century England.[4] Each treatment has failed to identify, or fully explore, the crucial factor uniting his activities and attitudes: his involvement with the mathematical, technological, medical and social aspects of scientific progress in the seventeenth century. These failings have been due to past historiographical realities and have been highlighted by new attitudes to the importance of the history of ideas. This thesis argues that previous studies have perpetuated an incomplete picture of Petty's life and achievements, which can only be brought into correct focus by an examination of his role as a great seventeenth century natural philosopher. In turn, this examination of one important individual will, it is hoped, shed light on significant historical and historiographical issues which are currently exciting vigorous attention among scholars.

Finally, it is necessary to describe the manuscript sources used in the present study, to reinforce the view that this fresh approach to Petty's intellectual biography is dependent upon, and justified by, analysis of hitherto unexplored or undervalued material. The main body of Petty manuscripts, known as the 'Petty Papers', is located at Bowood House in Wiltshire. Although used as a source for various works, including Fitzmaurice's

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1. A good instance of this approach is in Hull, Economic Works, i, vii, 'The writings of Sir William Petty may be roughly divided into three classes. The first relates to his activities as surveyor of forfeited lands in Ireland under the Protectorate; its present interest is chiefly biographical. The second includes his papers on medicine and on certain mathematical, physical and mechanical subjects. These are now forgotten. The third class comprises his economic and statistical writings. The merit of these has been freely recognised.'
2. The Double Bottom or Twin-hulled Ship of Sir William Petty, ed., the Marquis of Lansdowne (London, 1931). Keynes, Bibliography, pp.43-45.
3. Y.M.Goblet: La Transformation de la Geographie Politique de L'Irlande au xviii^e siecle dans les cartes et essais anthropogeographiques de Sir William Petty, (Paris, 1930), Keynes: Bibliography, p.50.
4. R.F.Jones: Ancients and Moderns, (second ed., Los Angeles, 1961) especially 89-92, 172-173. For a list of other sources on Petty see my review of Keynes, Bibliography, in Brit. J. Hist. Sci., 6 (1973), 321-322.

Life of Petty, Larcom's History of the Down Survey, Pender's Census of Ireland, and the excellent editions of selected papers by the Marquis of Lansdowne,[1] this vast collection has by no means been exhausted. Indeed, a private catalogue compiled by the present author revealed many unpublished items of great importance to an understanding of Petty's natural philosophy. However, even this splendid source has its limitations, since the collection of papers at Bowood originated, primarily, from the last thirty years of Petty's life.[2] Therefore, while they illuminate the detailed events of his post-Restoration career, and particularly his extensive publications (which mostly date from this period), they do little to elucidate the more mysterious, but in some senses more significant, years during which his attitudes and ideas were being formed. This unfortunate lacuna has therefore been filled by a number of additional sources, of which the most important is the enormous body of Hartlib manuscripts housed in Sheffield University Library.[3] This magnificent collection, which reflects the indefatigable labours of the greatest reformer in seventeenth-century England, is particularly significant as far as Petty's natural philosophy is concerned, because in 1647 Hartlib drew the brilliant young Baconian into his orbit, stimulating him to provide schemes, plans, and outlines of his

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1. The History of the Down Survey, by Doctor William Petty, A.D. 1655-1656, ed., T.A.Larcom (Dublin, 1851), cf. Keynes, Bibliography, p.49. This is partially based on B.H. MSS. Volume 23; A Census of Ireland, circa 1659 ed., S.Pender (Dublin, 1939), based on B.H. MSS. 41, Box 'L'; The Petty Papers. Some unpublished writings from the Bowood Papers, ed., Marquis of Lansdowne (London, 1927) cf. Keynes, Bibliography, pp.65-71; The Petty-Southwell Correspondence, 1676-1687, ed., Lansdowne (London, 1928), taken mainly from B.H. MSS. Volumes 7, 9 and 10. Cf. Keynes, Bibliography, p.71; The Double Bottom ... op.cit., taken primarily from B.H. MSS. Volumes 20 and 21. Cf. Keynes, Bibliography, p.43. Extensive comparison between manuscripts and edited texts has indicated generally accurate transcription.
2. Obvious exceptions to this rule are B.H. MSS. Volumes 3, 24-29 and 40, Box L. See bibliography below, for a list of manuscripts at Bowood which constitute the 'Petty Papers'.
3. These papers are currently being catalogued; the present work has necessarily relied on the older, less systematic ordering.

views and activities on a myriad number of subjects. Many of these manuscript exercises have remained with the Hartlib papers and they help to provide new insight into Petty's early activities in London and Oxford, between 1646 and 1652. In addition, another set of letters from Petty to Hartlib has been located in the Osborn collection (at Yale University)[1] and a much more thorough search has been made into the Bell Papers at the British Museum, the Pepys Papers of Magdalene College, Cambridge, manuscripts in the Royal Society Library, and papers at Oxford in Worcester College Library and the Bodleian. These, and a number of less significant sources, have provided new information, which, when allied with the fresh axis of enquiry adopted by this study, has provided a more unified and comprehensive picture of the intellectual origins and achievements of this important English natural philosopher.

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1. I would like to thank Dr. T.Barnard and Charles Webster for bringing these papers to my attention.

Chapter 1

The Life of a Natural Philosopher

'He has told me that whereas some men have accidentally come into the way of preferment by lying at some inne and there contracting an Acquaintance; on the roade; ... he never had any such like opportunity, but hewed out his Fortune himself.'

Bodleian Library, M.S.Aubrey 6, f.15.

'To conclude, he was a person of an admirable inventive head, of a prodigious working wit, and of so great worth and learning, that he was both fit for, and an honour to, the highest preferrment.'

A.Wood, Athenae Oxoniensis, iv, 217.

'The common and verbal philosophies are of that nature that whosoever hath most witt will get the better of his adversarie, but real experimental learning is for truth, and whosoever can make out by visible experiment that which hee undertakes hee will evince that hee hath the truth. For all knowledge must bee brought before their true judges which are either demonstration or sense and experiment, the rest is meere wit or rhetorick.'

Sheffield University Library, Hartlib M.S. Ephemerides, 1649, B-C3, reporting Petty's credo, as expressed in private conversation.

Chapter 1: The Life of a Natural Philosopher:

(a) Childhood and Adolescence: 1623-1643:

William was born on 26 May, 1623 into the family of Anthony and Francesca Petty, the eldest surviving child among six brothers and sisters. His father, working in the increasingly depressed conditions of the Hampshire cloth industry, was a clothier and dyer who ran a small-scale business in the market town of Romsey. The family came from the lower end of the social scale, and, as relatively poor artisans, needed to supplement their commercial income by cultivating a small plot of land.[1]

In an account of these humble origins, which was later given to John Aubrey,[2] Petty stressed that as a child he was surrounded by many basic trades and industries:

> 'Rumsey is a little Haven towne, but hath most kinds of Artificers in it: when he was a boy his greatest delight was to be looking on the Artificers, e.g. smyths, the watchmakers, carpenters, joyners etc. and at twelve years old could have worked at any of these trades ...' [3]

This early experience, combined with the influence of his family's commercial occupation to leave an indelible mark on Petty's character and outlook, and helped to create his distinctively utilitarian attitude to social and scientific problems. In addition to these environmental influences, Petty also received a formal education from the local Schoolmaster. Later in his youth he expressed disdain for such training, a contempt which was to recur throughout his life:

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1. See Strauss, op.cit., p.20. For the depression in Hampshire's cloth industry cf. B.E.Supple: Commercial Crisis and Change, 1600-1642, (Cambridge, 1964), pp.116 and 129.
2. Aubrey's biographical account, collated from various manuscripts, is in Keynes, Bibliography, pp.85-92.
3. Ibid, p.85.

'I who a Country Boy was put to Schoole
Where I was borne, to a pedantic fcole
And there formed verbs, did scan, construe & parse,
Make Verse & Themes, but all to save my - ...' 1

However scurrilous or deprecating Petty's opinion of his schooling may have been, this basic grammatical education provided a groundwork of literacy on which he was able to build. Thus, by the age of twelve he possessed 'a competent smattering of Latin & was entred into the Greek ...' and was sufficiently skilled to give lessons in Ovid's Metamorphoses, and readings in basic devotional literature, to less literate neighbours and relations.[2]

Nonetheless, for a youth possessing a brilliant mind, a remarkable memory[3] and exceptional energy, the limited world of a small Hampshire town soon became restrictive. Early in 1637 Petty left Romsey and made his way to the South Coast, where he signed on as cabin boy in a small ship which traded between England and the North-West Coast of France. It was during the ensuing ten months of service that his life-long fascination with naval matters first developed, and it was also at this point that he gained a basic grounding in navigational mathematics.[4] However, these skills (combined with the restricting, and potentially dangerous, problem

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1. An English translation of Petty's Latin verses 'Ad Patres Soc. Jesu Cadomaeos. An°.1637' is at B.H. MSS. Volume 7, no.2. The Latin original, at B.H. MSS. Volume 2, No.7, is reprinted in Petty Papers, ii, 245-246.
2. Cf. Aubrey's account, Keynes, Bibliography, p.85. and Lansdowne, P.S.C., p.216, Petty to Southwell, 14 July, 1686: 'When I went to sea, 6d. was given (or rather paid) mee by Mother Dowling, who having been a sinner in her youth, was much releived by my reading to her in the Crums of Comfort, MR Andrews' Silver Watch Bell and The plain man's pathway to Heaven. The next 6d. I got [from] Len Green for often construeing to him in Ovid's Metamorphoses ...'
3. Lansdowne, P.S.C. pp.283-284, Petty to Southwell, 16 August, 1687, 'Concerning an Artificial Memory ... I myselfe had somewhat of the Latter, and could att first hearing remember any 50 Nonsensicall Incoherent words; and not onely repeat them readily forwards and backwards, but alsoe readily which was the 3rd, 19th, 37th etc ...'
4. Fitzmaurice, Life, (Petty's Will) pp.318-319; P.S.C. pp.216-217. See below, Chapter 3, pp. 253-4 for an examination of the instructional and navigational texts used by Petty.

of acute myopia) did not endear the young sailor to the captain and crew. After breaking his leg on board ship Petty was unceremoniously stranded in France by his shipmates. Relying on his already acute business acumen, he maintained himself by trading in small household articles and waited for the limb to heal.

During this recuperative period the young foreigner indulged in an important process of self-examination. As a result of this analysis Petty decided to alter the course of his life. Realising that a career at sea would not offer the greatest potential for self-advancement, and that the key to his progress lay in further education, he applied to the Fathers of the Jesuit Seminary at Caen for permission to become a student. This application, in the form of a Latin poem, gave an account of his life up to 1637. The verses make it clear that even at this early stage in his career, he could view his experience with an attractive candour. Beneath the jejune, poetic phraseology, there appears an unsentimental acceptance of the value of further education and his own need to undergo such training: in particular, he emphasised the constructive benefits of the course's geographical, historical and rhetorical elements.[1]

As Petty later realised, this decision to attend the Jesuit college at Caen was one of the most important events in his career.[2] There can be no doubt that by 1630 the method and content of the Jesuit curriculum provided the most exacting and stimulating educational environment then available in France. Indeed, for certain subjects, the more competent Jesuit colleges were the equal of any continental university. Petty shared this creatively demanding experience with such notable contemporaries

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1. B.H. MSS. Volume 7, no.3.
2. Aubrey's account, derived from Petty's description, Keynes, Bibliography, p.86, ' ... this I guessed was that most remarkable accident that he meant.'

as Mersenne, Descartes[1] and Peiresc, who openly acknowledged their debt to the Jesuit Fathers. Petty's education at Caen, however, presents difficulties for the intellectual biographer, not only because information about the specific curriculum of this college is restricted, but also because the exact duration of his stay is hard to determine. Therefore, it is only possible to construct a tentative picture of his studies by combining his own cryptic comments with more general material on the sources and didactic methods adopted by the Jesuits.

It has already been noted that when he applied for a place in the seminary, Petty specifically asked to attend 'ye first classe of your renowned College of Geography'.[2] Within the Jesuit curriculum the subject of geography embraced the widest applicable range of skills and information.[3] These techniques and the catholic nature of the course, reflected the vigorous and widespread missionary work of the order and the requirements of an education designed to produce military officers, surveyors, and skilled recruits for the country's growing maritime interests. Thus the study of geography at colleges like La Fleche and Caen incorporated elements of rhetoric, philosophy, languages, mathematics, hydrography, hydrostatics, economic geography, political theory and broadly-based natural history. This highly flexible and non-formal approach usually depended as much on the personal inclinations of the

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1. Descartes referred to La Fleche as: 'l'une des plus, celebre ecoles de l'Europe.' Cf., J.F.Scott, The Scientific Work of Rene Descartes, (1596-1650), (London, 1952), p.1; for the college of La Fleche see: C. de Rochmonteix, Un College des Jesuites aux XVIIe et XVIIIe siecle: Le College Henri IV de La Fleche, (Le Mans, 4 volumes, 1889) especially iv, 46 et seq; for Peiresc see, L.M.Marsac: 'The Humanist as Scientist: Nicolas Claude Fabri de Peiresc' Cahiers d'histoire Mondiale, 8 (1964-1965), 93-99. The author would like to thank Dr. C.Schmitt and Dr. A.Gabbey for suggesting valuable sources on Jesuit education.
2. B.H. MSS. Volume 8, no.3.
3. This section is based on the extensive monographs by Pere F. de Dainville. See: La Naissance de L'Humanisme Moderne, (vol.1. of, Les Jesuites et L'Education de la Societe Francaise: Paris, 1940) and, La Geographie des Humanistes, (vol.2. of the above series, Paris, 1940), henceforward, Dainville, Geographie.

seminarists as on the official educational programme outlined in the Ratio Studiorum. But it is clear that, in individual terms, study in the 'College of Geography' at Caen helped to lay the foundations on which Petty's later fortune, reputation and scientific methods were to rest.

In the first instance the young Englishman's exposure to the Jesuits' ever-expanding geographical knowledge, (derived from histories published by missionary members of the Order) created within his mind a powerful bias towards the process and genre of natural history. Between 1600 and 1660 over three hundred accounts, covering voyages to China, Japan, South America, India and the Middle East, were published.[1] As the years passed these natural histories became increasingly systematic and included information on almost every aspect of geographical, topographical and economic life. Progress in systematisation was matched by parallel advances in classificatory and scientific technique. Educational methods in the college to some extent matched these developments and were positively embodied in the new programme instituted at La Fleche in 1651.[2] The extent to which Petty came into contact with this new geographical information is hard to determine. If, for example, he only stayed at the college for a year, it is unlikely that he penetrated sufficiently into the course to deal with the most sophisticated material. However, even at a simplified level, the important features of programmatic natural history would have registered with him, since he necessarily began his studies by consulting a standard text-book such as Introductionis in Universam Geographiam.[3] Although the information and techniques embodied in this work are limited and unsophisticated, the material is nevertheless

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1. Dainville, Geographie, pp.130-131, 150 and 370 for these natural histories.
2. Ibid, 198-199.
3. Cluverius, Introductionis in Universam Geographiam, tam Veterum quam Novam, Libri vi, (Leyden, 1624). Dainville reports that this work by the Professor of Geography at Leyden went through twenty-nine editions after 1629, cf. Geographie, p.180.

organised according to systematic and clearly-structured geographical classifications. The fundamental concept guiding this procedure, that of an ordered, empirical approach to knowledge and problem-solving, was also one of the basic methods later adopted by Petty in his work as an exponent of Baconian scientific principles.

If the study of geography at Caen helped to create within Petty a predisposition towards inductivism, then it also gave him a basic grounding in some crucial skills, the most notable of which were applied mathematics and a command of various languages. As one would expect from a 'standard' arts course, the students at Caen were raised to a moderate level of linguistic proficiency. Petty was no exception, and as Aubrey later reported: 'Here he learnt the French tongue & perfected himselfe in the Latin and had Greeke enough to serve his turne.'[1] Thus his earlier, albeit unimaginative, grounding in Latin and Greek proved useful: his particular skill in Latin enabled him to produce an excellent verse translation of Psalm 104 over thirty years later, which John Evelyn was to describe as 'inimitable.'[2] Petty's facility in the classical languages was partially a response to the innovatory methods of teaching adopted by the Jesuits, who included within the arts curriculum standard authors such as Aristotle, Homer, Cicero, Caesar and Varro. All these Petty later acknowledged as being among the greatest and most sagacious of early writers.[3] Within the school of geography, however, in an attempt to give the training in rhetoric and classical languages more intrinsic interest,

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1. Keynes, Bibliography, p.86.
2. For Evelyn's description of Colloquium Davidis see Keynes, Bibliography, p.95. Evelyn also said, 'There is not a better Latine poet living, when he gives himselfe that Diversion ...' Ibid. p.94. For the poem itself cf. ibid, pp.15-16. See also G.Keynes 'An Unrecorded Poem by Sir William Petty' The Book Collector, 23 (1974) 179-186; Lansdowne, Petty Papers, ii, 242-255, 'Verses'.
3. Lansdowne, P.S.C., p.158, Petty to Southwell, 21 September, 1685, where Petty lists the great classical writers.

the reading matter and tuition often centred on 'geographical' subjects and texts. It was at this point that Petty probably came to admire the incisive, polished and epigrammatic prose of Tacitus and the blend of history, geography and anthropology found throughout his works.[1]

Within the geographical curriculum of Jesuit Colleges at this time, the emphasis laid upon applied mathematics and abstract geometry was of cardinal importance in the development of Petty's attitudes to natural philosophy. As an individual student he was particularly fortunate in this field, since he studied under the direction of the great maritime scientist and natural historian, P.Georges Fournier.[2] His magisterial and encyclopaedic work, Hydrographie Contenant La Theorie et La Pratique de Toutes Les Parties de La Navigation ...[3] exhibits the type of mathematical expertise (pertaining to navigation, hydrographic surveying, naval architecture, hydro-statics and the dynamics of moving bodies) which was included within the subject of geography at Caen. Even at an introductory level the course also incorporated basic instruction in the mathematics of astronomy, cartography, surveying and geometry. Thus Cluverius prefaced his introductory text with a chapter outlining the divisions of the globe, use of the calendar, points of the compass and basic navigation.[4] Further mathematical training at Caen would probably have developed along lines suggested in basic text books by Christopher Clavius. In particular his Geometria Practica and Epitome Arithmeticae Practicae,[5] which were almost universally adopted in Jesuit colleges, gave

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1. Ibid, loc. cit, Tacitus was on the same list. In Jesuit colleges training in rhetoric often included disputations on 'geographic' subjects such as the political, economic and geographical topography of contemporary France. Cf. Dainville, Geographie, p.179.
2. Cf. ibid, Chapter 3, especially pp.257-272.
3. This work appeared in 1644 and was reprinted at Paris in 1667.
4. P.Cluverius, Introductionis ... op. cit., Book 1.
5. C.Clavius: Epitome Arithmeticae Practicae, (Rome, 1585); C.Clavius, Geometria Practica ... (Rome, 1604).

the average student an excellent working knowledge of mercantile arithmetic and the basic techniques and instruments used in contemporary surveying. Designed as a complete training for future military surveyors, estate owners, merchants and navigating officers, this emphasis on applied mathematics was so strong at colleges like Caen and La Fleche, that Descartes was later to say of his own experience:

> "Beyond all I was most pleas'd with the Mathematicks, for the certainty and evidence of the reasons thereof; but I did not yet observe their true use, and thinking that it served only for Mechanick Arts; I wondered, that since the grounds thereof were so firm and solid, that nothing more sublime had been built thereon." [1]

This ambivalent encomium was, in fact, slightly unfair. For any instruction based on the general Opera[2] of a standard author like Clavius inevitably followed his exegesis of a wide range of mathematical and geometrical traditions, drawn from classic authors such as Euclid, Archimedes, Apollonius and Ptolemy. Indeed, it was precisely this type of mathematical training which soon enabled Petty to compose his treatise on: 'A Systeme of Astronomy (Ptolemaical, Copernican)' in 1638.[3]

The assumption that Petty, like Descartes and Mersenne, experienced and benefited from the mathematical training contained within the geographical curriculum, is confirmed by his own specific reference, nearly fifty years later, to the value of such instruction:

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1. R.Descartes: A Discourse of A Method For the well guiding of Reason, And the Discovery of Truth in the Sciences, trans., Anon, (London, 1649), p.12. [Bodleian Reference: P.219. ART].
2. C.Clavius, Opera Mathematica, (1612). This magnificent book, five volumes in one, surveys most classical sources of geometry and mathematics, with particular concentration on Euclid. The work blends utilitarian with abstract interests and is presented in a carefully structured fashion.
3. Petty's list of writings in Petty Papers, ii, 260, no.158.

> 'In the first place, I declare and affirme that at the full age of fifteene years I had obtained the Lattin, Greeke, and French tongues, the whole body of common Arithmetick, the practicall Geometry and Astronomy conducing to Navigation, Dialing etc., with the knowledge of severall Mathematicall Trades ... at the University of Caen ... ' 1

Furthermore, the Jesuits' combination of a broadly-defined view of natural history, with cartographic and more general techniques of quantification, was of profound importance to the subsequent development of Petty's attitude to science and political arithmetic. Not only was this education to provide him with sufficient skill and insight to appreciate revolutionary progress in several mathematical fields, but it also gave him a basic competence in the techniques on which his reputation as a great early English cartographer and surveyor now rests. The potentiality and fertility of such skills, and their alliance within the geographical curriculum at Caen, are therefore of great significance when the origins of Petty's scientific methods and achievements are considered.

Petty's brief study of systematic logic under the direction of the Jesuits also left a profound mark on his intellectual development. In a poem addressed to the seminarists, Petty emphasised this as another subject in which he hoped to receive instruction: "Teach me ye arts of Truth and them apply T'unravell true and feigned mystery."[2] Almost certainly Petty's tuition in this subject would have been based on the brilliant and radical works of Francisco Suarez.

As the most complete and original proponent of the 'new scholasticism', Suarez enjoyed the highest reputation in Jesuit and Protestant

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1. Fitzmaurice, Life, (Petty's Will), pp.318-319.
2. Poem, B.H. MSS. Volume 7, No.3.

universities during the first half of the seventeenth century.[1] Like many other Jesuit educationalists in France the Fathers at Caen used his works as instructional texts for student exercises in logic, metaphysics and philosophy. These exercises made a deep impression on Petty, and in later life he included Suarez within the ranks of a second select group, containing the greatest modern authors.[2] As with mathematics it is again the case that his high regard for the great post - Thomist philosopher was shared by Descartes, who also encountered his works during a typical Jesuit education. Although Petty and Descartes later took a generally dismissive view of scholastic philosophy, they both revered the acuity, lucidity, and logical techniques of Suarez, and the great Frenchman carried a copy of the Disputationes Metaphysicae on all his travels.[3]

Occupying a terminal position in the development of neo-scholasticism, Suarez moulded and perfected the technique of the quaestio, and his method can be regarded as the climax of a long evolutionary process. Whenever this method is applied in his works it always adopts substantially the same form. Firstly, he defines the precise terminology and the general nature of the question. Next, he surveys all the literature

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1. See: F.Suarez, On the Various Kinds of Distinctions. trans., & ed., C.Vollert, (Milwaukee, Wisconsin, 1947); F.Suarez, On Formal and Universal Unity, trans., J.F.Ross (Milwaukee, 1964); R.Wilenius, The Social and Political Theory of Francisco Suarez, (Helsinki, 1963); M.Lundberg, Jesuitische Anthropologie und Erziehungslehre in der Fruhzeit des Ordens (c.1540 - c.1650). (Acta Universitatis Upsaliensis: Studia Doctrinae Christianae Upsaliensa, Volume 6, Uppsala, 1966); E.Brehier, The History of Philosophy, The Seventeenth Century, trans., W.Baskin, (Chicago, 1966) p.1, 'The Jesuit Society, which had more than two hundred schools in France, provided educators, spiritual directors, and missionaries. Thomism as formulated by the Jesuit Suarez was universally taught and finally supplanted the doctrine of Melanchthon, even in the universities of Protestant countries.'
2. P.S.C., p.158.
3. Suarez, On the Various ... Distinctions, trans. Vollert, op.cit.,p.[5] For Descartes' mastery of contemporary scholasticism, and the origin of his attitudes towards this type of philosophy, see: G.Sebba, Bibliographia Cartesiana, A Critical Guide to the Descartes Literature, 1800-1960, (Volume 5 of: International Archive of the History of Ideas, The Hague, 1964) pp.60-61, 82, 87.

which in the past had discussed the problem, and provides a scrupulously accurate summary of the principles, procedures, and conclusions, of these arguments. In many instances he then adduces new opinions to support the ideas of his opponents. Having summarised and presented the history of the problem, Suarez then proceeds to a minute destruction of the opinions which he rejects. Finally, he presents a statement of, and supporting arguments for, what he reasons is the true, or at least most probable, opinion. Behind the baroque exterior of complex argument and counter-argument, there exists a well-defined, architectonic framework.

While this clear, but sophisticated structuralism undoubtedly impressed him, there were several other more crucial influences in the methodology of Suarez which left their mark on the young English student. At all times, whether or not he utilised the classic syllogistic form, Suarez endorsed his fundamental belief that the only viable approach to a problem came through the exercise of reason, a procedure controlled not by emotion or prejudice, but by an apparatus of clearly-defined, linguistic and logical techniques. An equally intense rationalism was later to play an important part in Petty's radical, and occasionally unrealistic, attitude to economics, government, religion and society. It also helped create his strong belief in the need for verbal clarity and the formal definition of terminology as a prerequisite for discursive reasoning.[1] Secondly, the method adopted by the great neo-scholastic relied upon the systematic collection of existing facts and opinions. On this 'natural history' of logic and philosophy, Suarez then exercised a process of critical appraisal. This technique, when allied with close textual comparison and a controlled eclecticism, helped to produce new opinions

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1. For Petty's reliance on definition and his interest in the problems of verbal communication, see below, Chapter 3,pp. 275, 319 passim.

and ultimately a quasi-organic synthesis which was original and consistent. Once again, Petty's later support for histories of trade and rigorous socio-economic surveys, based on well-defined methodological principles, reflects the early influence of this empirical process. Finally, the social and political views of this gifted logician, helped mould Petty's own formless ideas at an impressionable stage. As will be seen in a subsequent chapter, the radicalism of the political theory enunciated by Suarez can be regarded as a source of various equally radical attitudes to society and government evinced by Petty in his adult career.

When he left France (in late 1638 or early 1639) Petty had grown from a precocious child into a self-reliant and impressive youth. The effects of his study at Caen, and possibly of a short visit to La Fleche,[1] were profound: from a brilliant, but unpolished schoolboy, he had reached an impressive level of intellectual refinement, discipline and erudition. He was proficient in four languages and possessed a number of vital mathematical skills. His training in the traditional arts was well advanced, and the geography course had supplied his mind with important matter, setting the direction which he would follow for the rest of his life. It is not surprising, therefore, that he himself regarded this stay in France as a 'most remarkable accident' which helped determine his subsequent career. Furthermore, it is unlikely that he could have received such a rigorous and stimulating experience in any other type

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1. Keynes, Bibliography, p.86. Aubrey summarised this section of his life as: 'Here (at Caen) he studyed the Arts. M[emoran]dum: he was sometime at La Flesche in the coll: of Jesuites: at 18 he was (I have heard him say) a better Mathematician then he is now...'

of educational institution.[1] Without this he could not have developed the particular blend of interests which later guaranteed his position as a leading seventeenth-century natural philosopher.

Petty's employment during the period 1639 to 1643 reflected that idiosyncratic ambivalence, between theory and profit, which was to characterise the rest of his life. After a short stay in London he returned to the sea, where, as he himself maintained, his previous training: "preferred me to the King's Navy ... [and] ... at the age of 20 years, I had gotten up three score pounds, wth as much mathematicks as any of my age was known to have'.[2] He was therefore able to employ to advantage the naval mathematics which he learnt at Caen. It is also possible that at this point Petty made contact with, and even studied under, William Oughtred, one of England's leading mathematicians.[3] However, once the Civil War had broken out in 1643,[4] and with his home town caught between the embattled armies of Waller and Hopton, Petty decided to continue his education in Holland. Consequently he embarked for the Low Countries in November or December, accompanied by his younger brother Anthony, who was to act as his servant and companion.

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1. To compare Petty's education at Caen with other possibilities see: M.H.Curtis, Oxford and Cambridge in Transition, 1558-1642, (Oxford, 1965); W.T.Costello, The Curriculum of Seventeenth Century Cambridge, (Cambridge, Massachusetts, H.U.P., 1958) especially pp.70-106 and 148-149; Sister Reif, 'The Textbook Tradition in Natural Philosophy, 1600-1650' J.Hist. Ideas, 30 (1969), 17-32; H.Kearney, Scholars and Gentlemen, Universities and Society in Pre-Industrial Britain, 1500-1700, (London, 1970); C.Hill, Intellectual Origins of the English Revolution, (Oxford, 1965), pp.301-314.
2. Fitzmaurice, Life, (Petty's Will) p.319.
3. See Chapter 3, p.284 for his link with Oughtred, and the importance of applied mathematics at this stage.
4. R.Luce, Pages from the History of Romsey, (Winchester, 1948), pp.60-65.

(b) Holland: medicine and natural philosophy, 1643-1645

The two years that Petty spent in The United Provinces were some of the most important of his whole life. On many levels - intellectual, professional, personal and scientific - the experience he gained in Holland, whether by accident or intention, had a lasting effect. Both his fundamental attitude to natural philosophy and his integration into the world of continental science depended on this experience,[1] and when presented with the chance of furthering his career Petty exhibited remarkable powers of assimilation and understanding.

The young Englishman's decision to go to the United Provinces reflected a well-established practice in his own country that became a sizeable diaspora as a result of the Civil War.[2] On his arrival Petty, like every other visitor, would have been overwhelmed by the social order, economic rationalism, and commercial prosperity of this small, but immensely powerful country. There can be no doubt that this experience left an indelible mark on his attitude to methods of social and economic organisation. It helped to create his fundamental belief in the need for a thorough reconstruction of English economic life, based on the systematic development of new technologies, and funded and controlled by an enlightened government. Many of the specific institutions and ideas subsequently put forward by Petty in his numerous tracts on economics or government were suggested by, or entirely derived from, models which he

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1. For the Dutch intellectual background see P.Dibon, La Philosophie Neerlandaise au Siecle D'or, Tome 1, l'Enseignement Philosophique dans les Universites a l'Epoque Precartesienne, (1575-1650), (Paris, Amsterdam, 1954) especially 41-43, 80-126.
2. C.Hill: Intellectual Origins, op.cit., has described this tradition, cf, pp.280-283: 'Citizens of London and East Anglia visited the middle-class republic of the Netherlands, as their betters went off on the grand tour'. More research is needed into the relationship between English and Dutch science and culture during this period. One excellent work is R.L.Colie: Light and Enlightenment, A Study of the Cambridge Platonists and the Dutch Arminians, (Cambridge, 1957).

had encountered in Holland between 1643 and 1645.[1] Above all, tangible evidence from the republic made Petty sensitive to the potentiality of social and economic improvement: in the well-run state poverty, unemployment and disease could be controlled, if only correct methods and mechanisms could be devised and implemented.[2]

While these general observations on the Dutch system were to have a profound effect on Petty's later view of government and society, it is clear that at the time, both his reasons for going to Holland and his particular experience, reflected immediate concerns of a more specific nature. Although he first registered at Utrecht, the newest of the Dutch universities, late in 1643,[3] he soon moved on to Leyden. He was inevitably drawn to that particular university because of its growing international reputation, notably in the fields of medicine, law and oriental languages. Equally, the recent decision at Utrecht (following the bitter conflict between Regius and Voetius) which banned teaching of the Cartesian system and restricted all philosophic instruction to the writings of Aristotle, probably poisoned the atmosphere in the younger university and enhanced the attractions of its elder competitor.

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1. See below, especially Chapter 2, pp. 207-213.
2. It is now recognised that the Dutch economy reached a peak in the period 1649-1651. Petty therefore saw it in a period of sustained and successful expansion; cf. J.Stoye, Europe Unfolding. 1648-1688 (London, 1969) pp.140-149, especially p.147.
3. R.W.I.Smith: English-Speaking Students of Medicine at the University of Leyden, (Edinburgh, London, 1932) p.181. Utrecht was founded in 1636, and first attracted medical students from Leyden because it adopted the innovative practice of extensive clinical instruction. For a brief discussion of the early clash over Cartesianism see, E.W.Ruestow, Physics at Seventeenth and Eighteenth-Century Leiden: Philosophy and the New Science in the University, (The Hague, 1973), pp.35-36. (subsequently, Ruestow: Leiden Physics).

In 1643 Leyden's intellectual and commercial vigour were remarkable. The second Dutch city in terms of population, Leyden was by mid-century probably the largest single industrial concentration in Europe, surpassed as an industrial town only by Lyons.[1] The major industry was, of course, based on the manufacture of cloth, and Leyden's prosperity and commercial life reflected this dominating influence at every level. As William Aglionby, another English visitor noted:

> "Here is the great manufacture of that excellent Cloths which are transported all the world over; they cannot make any such any where else. The fine Wool comes from Spain, and the course from England and Pomerania. All sorts of Nations work in the manufacture where many other Stuffs are made." [2]

Along with the wide variety of associated industrial activities such as dye-making, machine production, and the specialised stages of cloth manufacture themselves, there also existed a highly developed economic infrastructure of guilds, credit banks and property marts. Raised on this bedrock of economic prosperity and sophistication was a city administration which solved problems like architectural planning, sanitation, fire prevention, and social and medical welfare with outstanding efficiency.

On the basis of this vigorous and successful matrix, Leyden was able to maintain a university that by 1643[3] was the equal of any in Europe.

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1. C.Wilson, Economic History and the Historian : Collected Essays (London, 1969) pp.116 and 101. This estimate is supported by contemporary English visitors: cf., J.Ray, Observations ... Made in a Journey Through Parts of the Low Countries ... (London, 1673), p.31, 'Leyden is next to Amsterdam I think the greatest City in Holland and well built ...'
2. W.Aglionby: The Present State of the United Provinces (London, 1669), p.250. For Aglionby's excellent description of Leyden see, ibid, pp.241-270.
3. For a detailed history see Leiden University in the Seventeenth Century, An Exchange of Learning, ed., Th.H.L.Scheurleer, et. al., (Leyden, 1975), especially pp.1-19, 160-175, 216-343.

Apart from ill-judged remarks by Sir William Brereton,[1] the consensus of published opinion amongst English visitors to the city during this period uniformly supports the university's reputation for academic excellence and intellectual vitality.[2] Founded in 1572, Leyden University had undergone rapid growth during its first seventy years and by the 1640s its highly cosmopolitan student body numbered over one thousand. These students, drawn by the university's growing reputation, religious tolerance, relatively free intellectual environment, and the comparative stability and prosperity of the country, came from all over northern and eastern Europe.[3] Academic organisation followed the traditional pattern established in northern countries, with three higher faculties of theology, medicine and law, and a lower preliminary faculty of arts or philosophy. The curriculum of this last, propaedutic section covered logic, physics, ethics and, unofficially, metaphysics. To these were added Latin, Greek, mathematics, Hebrew, history and Arabic. Movement between the various faculties was fluid and did not depend on successful completion of the introductory arts course.

Although Petty registered as a medical student in one of the higher faculties, it is clear that he also attended preliminary lectures in

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1. Sir W.Brereton: Travels in Holland ... [and] ... the United Provinces 1634-1635, ed., E.Hawkins (Chetham Society, 1844) p.39. Brereton was, however, inspired by economic, technological, and industrial aspects of Dutch life, ibid, p.46, and pp.14-16.
2. For other descriptions see, Aglionby, op.cit., pp.245-248: 'Here has alwayes been very famous professors in all faculties; but particularly the Civil Law and Physick ...'; J.Ray, op.cit., pp.31-37; P.Skippon, 'An Account of a Journey Made through Part of the Low Countries ...' [1663] in : A Collection of Voyages and Travels, ed., A. and J.Churchill, (London, 1752) vi, 413-414; E.Veryard, An Account ... [of a] ... Journey through the Low Countries ... (London, 1701), pp.7-8; W.Carr, Remarks of the Government of Severall Parts of Germanie ... but more particularly of the United Provinces, (Amsterdam, 1688), pp.15-18.
3. Ruestow, Leiden Physicks, pp.1-13.

physics, logic and metaphysics. This practice was quite common since medical students at Leyden had traditionally emphasised physics in their philosophical orientation.[1] It is therefore likely that Petty made his first substantial contact with the opinions of Descartes within the physics course at Leyden university. The controversy which first broke out at Utrecht in 1636, had by now transferred itself to Leyden, and from 1642, instigated and supported by Adriaan Heereboord the young professor of logic, students were openly debating theses of Cartesian inspiration.[2] This increasingly active, and subsequently acrid discussion, would certainly have engaged the attentions of the young medical student from England. The nature of Heereboord's personal view of Cartesianism was not one of whole-hearted acceptance, and while he was prepared to adopt Descartes' emphasis on conceivability, as a criterion of reality, he was not, for example, willing to accept the Cartesian definition of matter as pure extension. Heereboord exemplified a transitional phase in continental science in which many proponents of the 'new' natural philosophy proved incapable of eradicating elements of the 'old' scholasticism. He did, however, strongly support the particulate theory of matter which Descartes advanced as one of the basic features of hypothetical physics, and his support may well have introduced Petty to serious consideration of this aspect of science.[3]

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1. Ibid, p.11. See also Petty Papers, ii, 261, List of Petty's writings, '1644 : Collegium Logicum et Metaphysicum.'
2. Ruestow, Leiden Physics, pp.34-60, Chapter 3. For a broader discussion of the debate over Cartesianism see: E.J.Dijksterhuis, et. al., Descartes et le Cartesianisme hollandais, (Paris, Amsterdam, 1950) especially pp.183-260; C.L.Thijssen-Schoute, Nederlands Cartesianisme (Amsterdam, 1954); and R.L.Colie, op.cit., pp.49-52.
3. See below, Chapter 3, section f, for an analysis of Petty's views on the 'mechanical philosophy'.

Despite Heereboord's failings, which added to these elements of scholastic revisionism a complete lack of experimental work, he proved to be a fertile influence within Leyden's academic community. His passion for dialectic dispute was allied with a determination to read, and freely discuss, any author whose works were informative or relevant to contentious problems in natural philosophy. He therefore incorporated, within the discussion, ideas suggested by Vives, Ramus, Patrizzi, Campanella, Telesius, Bacon and Comenius.[1] Although Descartes still took pride of place, Heereboord devoted special attention to Bacon and Comenius. This broad and controversial selection of authors, and the debate it engendered, acted as a catalyst within the university, and helped to create the ferment and intellectual turbulence of the next two decades.

Partly as a response to this growing controversy, and partly as a causal factor, the country's publishing firms, especially the great press of the Elzeviers at Leyden, poured forth an increasing number of works concerned with the new natural philosophy. Thus, the famous edition of Descartes' Discours de La Methode[2] first appeared at Leyden in 1637. The same author's Specimina Philosophia[3] was published by the Amsterdam branch of the Elzevier press, in 1644. The works of Bacon appeared in a steady stream: Latin editions of the Essays, Political and Moral were published at Leyden, in 1641 and 1644 (two editions), Novum Organum and

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1. A.Heereboord, Meletemata Philosophica, Maximam Partem, Metaphysica, (Leyden, 1654) 'Ad curatores epistola', pp.9-10 and 334-5. Bacon's works were also infused with classical ideas. See R.E.Larsen, 'The Aristotelianism of Bacon's Novum Organum' J. Hist. Ideas, 23 (1962), 435-450, for an unbalanced, but informative account. For Heereboord's debt to Burgersdijk, Professor of Philosophy at Leyden from 1620 to 1635, see Dibon, op.cit., 94-95, 107-119.
2. R.Descartes, Discours de La Methode pour bien conduire sa raison et Chercher la verite dans les sciences. Plus La Dioptrique, Les Meteores et La Geometrie. Qui sont des essais de cete Methode, (Leyden, 1637). See also, D.W.Davies, The World of the Elseviers, 1580-1712 (The Hague, 1954), pp.53-75.
3. R.Descartes, Specimina Philosophiae seu Dissertatio De Methodo Recte regendae rationis et veritatis in scientis investigandae: Dioptrice, et Meteora. Ex Gallica translata, et ab Auctore perlecta variisque in locis emendata, (Amsterdam, 1644).

De Augmentis Scientiarum were also on sale there in 1645, editions of Historia Ventorum were printed in 1638 and 1648, and earlier, in 1636 and 1637, Bacon's Historia Vitae et Mortis[1] was produced. Nor was Utrecht totally divorced from this action: thus Bishop John Hall's edition of Mundus Alter et Idem, which contained Campanella's Civitas Solis and Bacon's New Atlantis, appeared there in 1643.[2] These publications were the subject of comment and scrutiny in themselves, a phenomenon which is well illustrated by John Pell's remarks in a letter of July 1644, to Sir Charles Cavendish in France:

> 'Des Cartes his new booke de principiis Philosophiae is come out heere within these 3 or 4 dayes in 4° there is adjoined with it his Methode, dioptrique & Meteores (that is to say all ye Old booke save ye Geometrie) translated into Latine. But there are some few coppies printed without yt appendix for their sakes yt have bought ye French & understand it well inough. One may have of either for in yis crounce at Louys Elzeviers Shop' 3

Surrounded by these unavoidable influences and opportunities, Petty plunged with relish into this rich intellectual environment, to emerge two years later as an informed, questioning and articulate proponent of the new natural philosophy.[4] In a similar manner other great scientists,

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1. For these editions see, R.W.Gibson, Francis Bacon, A Bibliography of his Works and of Baconiana to the Year 1750, (Oxford, 1950), pp.xii-xvii, 'List of Editions' and passim.
2. Quoted by E.D.Blodgett 'Bacon's New Atlantis and Campanella's Civitas Solis: A Study in Relationships' Pub. Mod. Lang. Assoc., 46 (1931), 778 and n.48.
3. Brit. Mus. Sloane MSS. 4280 f.107v, dated July 20/30, 1644.
4. See A.E.Bell, Christian Huygens and the Development of Science in the Seventeenth Century, (London, 1947) pp.19-20. For the effects of a different Dutch environment on a great microscopist, see: M.Rooseboom, 'Leeuwenhoek, the Man: A Son of his Nation and his Time' Bull. Brit. Soc. Hist. Sci., 1 (1950), 79-85. See also Rooseboom, 'The History of Science and the Dutch Collections' Museums J., (1958), 199-208; W.Hackman, 'The Growth of Science in the Netherlands in the Seventeenth and Eighteenth centuries', in M.P.Crosland et al., The Emergence of Science in Western Europe, (London, 1975) pp.89-109; and, The Contribution of Holland to the Sciences, A Symposium, ed., A.J.Barnouw and B.Landheer (New York, 1943).

such as Swammerdam and Huygens, were products of this world. Thus, in 1645 (at age sixteen) Huygens came to Leyden to study law and mathematics. He was deeply influenced by contemporary debates, especially the one raging over Cartesianism, and benefited from the tuition of the Van Schootens (father and son), who successively occupied the Chair of Mathematics. In the same way, Petty's contact with progressive mathematics, and the work of Descartes and Bacon, which probably dates from this period, was of great importance to his intellectual development and, despite his subsequent criticism of the first of these two luminaries, he expressed a high regard for both natural philosophers throughout his career.[1]

In a very real sense, however, his experience of these intellectual currents was fortuitous rather than intentional, since his primary academic pursuit centred on the study of medicine. This was the faculty which, above all others, was responsible for Leyden's rapidly growing reputation throughout Europe's universities.[2] When he joined the 'physic line' in 1644, Petty was also joining a seventeenth-century British movement that, among many other notable doctors, included Sir Thomas Browne, Nehemiah Grew, Daniel Whistler and Sir Robert Sibbald.[3] Having paid the

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1. See below, pp.55-6 for Petty's ambivalent attitude towards Descartes and more abstract scientific methodology.
2. See: D.Guthrie, 'The Influence of the Leyden School upon Scottish Medicine', Med. Hist., 3 (1959), 108-122; G.A.Lindeboom, 'Medical Education in the Netherlands 1575-1750' in The History of Medical Education, ed., C.D.O'Malley, (Los Angeles, 1970); R.W.I.Smith, English Students of Medicine at Leyden, op.cit., pp.xii-xv.
3. Cf. C.Hill, Intellectual Origins, p.283; W.T.Stearn, 'The Influence of Leyden on Botany in the Seventeenth and Eighteenth Centuries' Brit. J.Hist. Sci., 1 (1962-1963), 137-158, especially 147. For Sibbald's experience at Leyden and Paris, 1660-1663, which closely paralleled Petty's, see: The Memoirs of Sir Robert Sibbald (1641-1722), ed., F.P. Hett, (Oxford, 1932) 56-58. Sibbald also studied under Van Horne and Vorstius and saw many demonstrations of morbid anatomy by Sylvius in the public hospital. Other pursuits were private anatomies, pharmaceutical chemistry, and private botanical collection in the environs of Leyden and Utrecht.

normal fee at his matriculation, and once inscribed as a member of the University, Petty naturally expected to remain at Leyden for a period of two years, in order to complete the course work. During this time he most probably defended in public several student exercises, each known as a 'Thesis exercitii gratia.' As with many other foreign students, the records establish that Petty did not graduate or defend a final thesis in the presence of The Praeses and other professors. The course that he joined was composed of four different elements, or areas of medical interest: classical medical theory, clinical instruction, anatomy, and botany coupled with the preparation of drugs. In all these areas Leyden maintained a well-warranted reputation. Each subject was taught as a regular component of the course during the university term, following a time-table set out in the printed syllabus. As a copy of this syllabus indicates,[1] four days of lectures each week made stringent demands on the conscientious student. However, if he attended every day to receive these five or six hours of instruction his training was, unquestionably, one of the most comprehensive and thorough then available in Europe.

As a student, Petty necessarily received much of his basic medical instruction at the hands of Dr. Albert Kyper.[2] Although not an intellectual radical, Kyper was not wholly dependent upon scholasticism in physics, or on a rigidly Galenic theory in medicine. Rather like

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1. J.Ray, Observations ... [on] ... the Low Countries. op.cit., pp. 32-34, gives the syllabus for 1663. This did not vary to any great extent during 1640-1665. In this timetable Dr. van Horne taught ordinary medical 'institutions' and methods at 8.a.m.; at 10 a.m. Dr. Vorstius gave interpretations of Hippocratic aphorisms; at 11.a.m. Dr. J.A.van der Linden instructed students in elementary medical practice, morbid pathology, prognosis and treatment, in accordance with the rational rules of medicine; at 2.p.m. Dr. Sylvius gave advanced tuition in practical and clinical medicine. Both van der Linden and Sylvius regularly carried out this instruction at the public hospital or 'Nosocomium.'
2. For a description of Kyper cf. Ruestow, Leyden Physics, pp.39-43.

Heereboord, though less imaginative than his younger colleague, Kyper can be regarded as a transitional figure who combined traditionalism and conservatism with certain specifically novel ideas. Thus, while generally following Galen and Hippocrates in his Anthropologia, Corporis Humani Contentorum,[1] he gave whole-hearted support to the Harveian theory of the circulation of the blood. Equally, in his earlier work Medicinam Rite Discendi ...[2] Kyper underlined the value and significance of clinical instruction within the medical course, while supporting classical ideas on prognosis and medication. Kyper's views are highly significant, since this clinical teaching was probably the most important medical innovation to be included within Leyden's curriculum. Adopted in May 1636 at the instigation of Dr. Otto van Horne, Professor of practical medicine, anatomy and surgery, this teaching method, which was derived from earlier experiments at Padua, received its first systematic emphasis at Leyden.[3] Kyper's description of van Horne's methods[4] is matched closely by John Northleigh's account nearly

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1. A.Kyper, Anthropologia, Corporis Humani Contentorum, et Animae Naturam et Virtutes Secundum Circularem Sanguinis Motum explicans, (Leyden, 1650). This book is a compendium of universal medicine intended for medical students. It discusses the best methods and intrinsic nature of medicine, describing briefly: innate heat, radical humours, anatomy, excrements, diet etc. In the preface Kyper signals the general acceptance of Harvey's doctrines at Leyden, cf. ibid, Sig ** 2.
2. A.Kyper: Medicinam Rite Discendi et Exercendi Methodus, (Leyden, 1643). The author's first elementary introduction to medical study; pp.250-255 stress the need for experience in hospital work, military surgery, and full instruction in instruments, dietetics, pharmaceutics, medicinal preparation etc.
3. Rooseboom 'Medical Education ... in the Netherlands' op.cit., 204-206. The method originated with da Monte (1488-1551), Professor of Medicine at Padua. A number of medical teachers at Leyden such as van Heurne (1543-1601), van Foreest (1522-1597), and de Bondt (1536-1599) trained at Padua and provided direct links between these centres of medical learning. See D.Guthrie, 'Influence of Leyden on Scottish Medicine', op.cit., 110-111.
4. Kyper, Medicinam Rite Discendi, op.cit., p.256.

sixty years later:

> 'The Sick that are entertain'd in the Hospital belonging to the University must subject themselves to the Rules of it, which are to admit the several Colleges or Lectures of the young Students in Physick, to determine what Remedies are most proper for each Patient's Case, each particular Student giving his Opinion, and the Professor his Approbation, who then writes a Receipt, and the rest of the young Students transcribe it; While they are here, if any poor come with a Note from a Burgomaster, they are advised for nothing, and so going round from one Bed to another, soon visit the whole House, and none that dies in it, but is liable to be dissected, so that Bodies are never wanting.' [1]

It is clear, therefore, that an outstanding feature of Leyden's course was the long-term emphasis on clinical instruction and this, as will later be shown, had a profound effect on Petty's own medical views. Another influence on his general attitude was probably the steady stream of medical tracts published at Leyden during this period. For example, great interest was expressed in the empirico-mathematical work of Sanctorius, whose important book De Statica Medicina appeared in 1642.[2]

If the clinical teaching at Leyden left a deep mark on Petty's medical outlook, then so too did the anatomical instruction. A general Dutch interest in the sick-room, dissection, and everything pertaining to medicine (captured so strikingly in the visual art of the period[3]) was soon embodied in the curriculum at Leyden. Thus the university's anatomical theatre, the second oldest permanent theatre in existence, was founded in 1597. Prior to this, Peter Paaw was appointed extraordinary

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1. J.Northleigh, Topographical Descriptions: with Historico-Political and Medico-Physical Observations: Made in Two several Voyages, Through most Parts of Europe, (London, 1702), pp.42-43.
2. S.Sanctorius, De Statica Medicina et de responsione ad Statio masticem Aphorismorum, (Leyden, 1642). Cf. A.Wolf: A History of Science, Technology and Philosophy in the 16th & 17th Centuries, (London, 1962), ii, 431-435.
3. W.S.Heckscher, Rembrandt's Anatomy of Dr. Nicolas Tulp, An Iconological Study (New York, 1958) gives a detailed description of this great example of Dutch 'medical' art.

professor in the subject,[1] inaugurating a long tradition of excellence in anatomical teaching, and the beginning of a northern resurgence of Vesalian and comparative anatomy. Paaw's new edition of the Epitome Anatomica by Vesalius was a notable product of this revival and, not surprisingly, was adopted in the Leyden School as a basic instructional text.[2] Almost certainly, however, Petty's main tuition, apart from van Horne's exposition of morbid anatomy, came from Johan de Wale.[3] By 1644 de Wale (Waleus) had become a leading experimental proponent of the Harveian theory, vigorously engaged in wide-scale dissection of animals and humans, and involved in a lively debate over the validity of blood circulation itself. At this time, therefore, Leyden was the major Dutch stronghold of Harveian thought, and Petty's later espousal of the theory in his public lectures at Oxford was directly linked to this early educational experience.[4] The other features of Leyden's anatomical instruction: osteology, comparative anatomy, and practical training in the

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1. Paaw (1564-1617) studied at Padua under Fabricius, Harvey's teacher, and was Professor of Anatomy at Leyden when the first anatomical theatre was built in 1597. This theatre was a high point in the visit of travellers. See Skippon, 'An Account of a Journey ...' op.cit., 414.
2. Andreae Vesalii Bruxellensis Epitome Anatomica. Opus redivivum cui accessere, Notae ac Commentaria. ed., P.Paaw, (Amsterdam, 1633 and also Leyden, 1616). Heckscher, Rembrandt's Anatomy, p.76: 'The medical faculty of Leiden had not only witnessed but actively engendered a Vesalius renaissance.'
3. G.A.Lindeboom, 'The Reception in Holland of Harvey's Theory of the Circulation of the Blood' Janus, 46 (1957), 181-200, especially 195-198.
4. See below Chapter 2, pp.223-233 for a more extensive description of Petty's subsequent medical career and attitudes. For works discussing Harvey's ideas in Leyden and Amsterdam, c.1637-1645, cf. G.Keynes, The Life of William Harvey, (Oxford, 1966) pp.449-452, especially, Descartes, (1637), Vesling (1637), Beverwijk (1638), de le Boe (1639), Drake (1639), J.Primrose (1639), Du Roy (1640), de Wale (1640), Rolfink (1640), Descartes (1643), Beverwijk (1644).

methods of dissection, also controlled and channelled Petty's rapidly evolving skill, and helped to mould his subsequent opinions about the subject. Above all, the detailed, private anatomical tuition that regularly took place under professorial direction in the University's auditorium medicum, engendered in Petty a contempt for the empty showmanship of public anatomies and a belief in the value of minute, painstaking explorations of the human body.

Botany, the final part of the medical course at Leyden, was another subject whose study helped to raise the university's international reputation.[1] The botanical garden, founded in 1587, was built up in the first few years by three great professors: Clusius, Lobelius and Dodonaeus. Benefiting from the rapid expansion of Dutch commercial activity, the gardens soon developed into one of the finest collections of medical plants in Europe. In 1625, Adolphus Vorstius took up the post of Praefectus Horti and he continued to teach and administer the institution until his death in 1663. Although rebuked for not keeping to the strict teaching requirements outlined in the printed schedule, Vorstius generally proved to be a diligent and effective botanical instructor. During spring and summer (March - September) he gave detailed expositions to medical students on all the relevant plants contained within the garden's small, crowded interior. These lectures were delivered by the side of each individual bed, and became one of the highlights of a visit by travellers to the university. From the extensive descriptions and lists given by Brereton and Skippon[2] it is clear that

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1. H.Veendorp and L.G.M.Baas Becking, 1587-1937. Hortus Academicus Lugduno Batavus. The Development of the Gardens of Leyden University, (Harlem, 1938), especially pp.68-76. 'Adolf de Vorst: (A.Vorstius) 1597-1663'; W.T.Stearn, 'The influence of Leyden on Botany ...,' op.cit., 138-147.
2. Sir W.Brereton, Travels ..., op.cit., pp.40-41: 'Herein was I this night, June 6, when Adolphus Vorstius, Doctor of physic, read his lecture in this garden, which he is to perform twice a week. His manner is to take a whole bed, four yards long and one broad, and to discourse of the nature and quality of every herb and plant growing therein, which he points out with his staff when he begins to speak thereof'. On this particular day Vorstius described the mastic tree, lupins, hyssop and hemlock.

detailed botanical knowledge was regarded as an integral part of the medical curriculum. During the winter months, Vorstius instructed the students on the properties and virtues of various minerals.[1] This constituted the other half of their basic instruction in the preparation of pharmaceutical products.

The immediate importance of this excellent medical training for Petty's future career is hard to overestimate, for when he returned to England it enabled him to pursue one of the classic routes to professional recognition and preferment. However, beyond a specifically medical context, the impact of this education was to have a profound effect on his general attitude to intellectual concerns and, in particular, to natural philosophy. The pursuit of medical knowledge whether in pathology, botanical taxonomy, morbid anatomy or the pharmaceutical preparation of minerals and chemicals, was not at this stage amenable to a more abstract, a priori scientific method. Instead, basic research relied upon meticulously detailed examination of diseased and dissected corpses, the systematic collection and organisation of botanical, pathological or anatomical data, an understanding of physiological mechanics, and an involvement with the grimy apparatus and experimental requirements of analytical chemistry. All these subjects inherently relied upon an inductive approach to scientific problems, and brought the researcher face to face with grim realities that were sensorily perceptible in a most immediate way. Beyond that, there was always the one unavoidable reality of failure or success in day-to-day medical treatment. This education created within Petty a predisposition for experimental work which

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1. For the Dutch background cf. J.W. Van Spronsen 'The Rise of Chemistry as an Independent Science' in Leiden University, op.cit., pp.328-343.

involved tangible materials and problems, and a passion for scientific subjects with direct utilitarian applications. Furthermore, as much as he can be described as an archetypal Baconian in later life,[1] it is crucial for an understanding of Petty's evolving natural philosophy to realise that the Baconian rationale confirmed, and gave form to, a profound combination of basic character, individual experience, and this particular type of intellectual training.

In addition to these academic pursuits in Holland, Petty also made a supremely important personal contact with John Pell, the young English Professor of Mathematics at Amsterdam University. This friendship can be regarded as one of the most significant in Petty's career, because through Pell he was probably introduced to Samuel Hartlib, and an English reform movement that in 1646 was forcefully re-emerging after the disasters of the civil war. More immediately, Pell provided Petty with open access to many leading figures in continental natural philosophy. Pell's function as a channel for Petty's interests and ambitions reflects the events in his own career, as a brilliant mathematical prodigy. 'Discovered' by Samuel Hartlib in 1629, Pell was later introduced to Theodore Haak, then Mersenne, and subsequently, with the help of Haak and Sir William Boswell, was elected to the vacant chair in Amsterdam.[2] With Mersenne's aid Pell was initiated into the world of

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1. Cf. R.F.Jones, Ancients and Moderns, p.91, 'Petty represents more clearly than anyone else the passion of the age, largely indebted to Bacon, for the concrete, the material, the useful, and the practical'.
2. For Pell (1611-1685) see D.N.B.; P.J.Wallis, 'An Early Mathematical Mainifesto - John Pell's Idea of Mathematics', Durham Research Review, 18 (1967), 139-148; J.Aubrey, Brief Lives, ii, 121-131; C.Hill, Intellectual Origins, p.44 and passim; P.R.Barnett; Theodore Haak : F.R.S. (1605-1690). The First German Translator of Paradise Lost, ('s - Gravenhage, Holland, 1962), pp.36-37 and passim. There are major collections of Pell manuscripts at the British Museum.

French science, and both men maintained fairly regular communication through direct correspondence or the intermediacy of mutual friends.[1] This intermittent contact continued from 1639 until Mersenne's death in 1648. Another correspondence of equal value sprang up between Pell and Sir Charles Cavendish.[2] This lasted between 1641 and 1652, when Pell came back to London, joining Sir Charles and Lady Margaret Cavendish who had themselves returned a year earlier.[3] The evidence provided by this abundant correspondence suggests that the young mathematician became increasingly involved with a wide range of developments in continental natural philosophy. Optics, geometry, algebra, mechanics, the mathematics of music, theoretical physics, dynamics and astronomy all featured in the letters as each subject provided points of immediate debate and interest. A flood of circumstantial information about events and personalities such as Hobbes, de Rheita, Gassendi, Mydorge, Toricelli, Roberval and Fermat flowed between the three epistolarians. As a result of these links Pell was immersed in the progress of continental science at a time when that progress was particularly rapid.

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1. For the Pell-Mersenne exchanges see: Correspondance du P.Marin Mersenne, ed., C. de Waard and B.Rochot, (Paris, Vols. i-xii, 1945-1972) Vols. ix-xii (1640-1643), under 'Pell' in index; P.J. Wallis, 'John Pell's Idea ...' op.cit., 145-147, for Mersenne's letter to Haak of 1 November, 1639, and Pell to Mersenne, 2 December, 1639.
2. The following sources contain portions of this correspondence: The Protectorate of Oliver Cromwell, ed., R.Vaughan (London, 1839), ii, Appendix, 345-382; H.Hervey, 'Hobbes and Descartes in the Light of some Unpublished Letters of the Correspondence between Sir Charles Cavendish and Dr. John Pell', Osiris, 10 (1952), 67-90; J.O.H.Phillipps, A Collection of Letters Illustrative of the Progress of Science in England from the Reign of Queen Elizabeth to that of Charles the Second, (London, 1841), passim; see also, J. Jacquot, 'Sir Charles Cavendish and his Learned Friends', Ann. Sci. 8 (1952), 13-27 and 175-191.
3. Cf. L.G.Sharp, 'Walter Charleton's Early Life' op.cit., 329-331 for the travels and scientific opinions of the Cavendish family.

Whether Petty was recommended to Pell through the good offices of their common tutor, William Oughtred, or whether he approached Pell on his own volition is not important: either way he was immediately hooked into this network of high-level contact that joined scientists throughout Europe like some invisible arterial system.[1] On an individual level, Pell himself provided Petty with current information about some of the most fertile subjects in contemporary natural philosophy, especially optics and mathematics.[2] In addition Pell's reliance on Petty for the distribution of his pamphlet at Leyden inevitably introduced his young assistant to many of the most influential natural philosophers within the city and its university. The four letters which the two Englishmen exchanged over this project also mark the earliest stage in Petty's life for which epistolary evidence still survives.

At the beginning of August 1644 John Pell wrote to his young colleague at Leyden, requesting him to distribute nine copies of his recently printed refutation of Longamontanus' book on the squaring of the circle.[3] Excusing his contentious activity on the grounds that his

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1. Pell's acquaintance with these scientists was at the highest level. See his description of a meeting with Descartes during February, 1645 in: H.Hervey, 'Hobbes and Descartes ...' op.cit., 77-81. Pell has been described as a Cartesian by R.L.Colie, Light and Enlightenment, op.cit., p.52. The precise nature of Pell's views are unclear, but there can be no doubt about his familiarity with Descartes' work.
2. For Pell's crucial role in the development of Petty's mathematical capabilities, see below, Chapter 3, pp. 285-288.
3. Brit. Mus., Sloane MSS. 4280, f.204r; letter Pell to Petty, undated except for: 'Amsterdam. Friday noone. To his much respected Freind, MR Petit.' A copy of Pell's pamphlet follows at ibid, f.205 + v. In this letter, Pell suggested that copies could be delivered to the following: ' ... MR. Golius, Schooten, Spanheimus, Waleus, Herbordus', and added: 'For the time and manner of doing it, I leave it wholly to your discretion. If you desire more coppies for your friends or acquaintance of our nation I shall send you as many as you desire. In the well managing of this business you may exceedingly oblige, Your assured friend & servant ...'

opponent's reputation would engender popular credence for this mathematical falsehood, Pell directed Petty to dispose of the copies as he thought fit. He did, however, suggest that his friend should take one copy to Joannes de Laet and ask for his advice on who the most appropriate recipients might be. Petty's reply a few days later[1] shows that he acted promptly and efficiently in his transmission of Pell's tract. Since de Laet only became available towards the end of this task, Petty's comments indicate that he was already well integrated with many members of Leyden's academic community.

The list of those whom Petty consulted over Pell's treatise is most impressive and includes James Gool (Golius), Claude Saumaise (Salmasius), de Wale, Van Schooten senior, Albert Kyper, Joncker Horghland and lastly, de Laet. Of these we have already met de Wale and Kyper, who were highly esteemed at Leyden, and who, as Petty reported, expressed admiration for a work which even Descartes regarded as excellent.[2] The rest of the names on Petty's list are all significant in one way or another. Van Schooten, although 'very old and indisposed' when he met Petty, was, like his son, a leading mathematical supporter of

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1. Brit. Mus., Sloane MSS. 4279, f.184. Petty to Pell, Leyden to Amsterdam, 14/24 August, 1644. This letter is printed in Fitzmaurice, Life, pp.8-9. In Brit. Mus. Sloane, MSS. 4279, f.134, Petty says 'Now Sir, I must thanke you for ye honour you have done mee as an Instrument in this your busines ... There are some in whom ... this your Magnum Opusculum hath begotten such an Opinion of your meritt that they resolve to go and live at Amsterdam to recyve your instructions.'
2. For Descartes' views on the refutation see H.Hervey, 'Hobbes and Descartes ... ' op.cit., 78-79, 'He praises my way of dealing with him [Longomontanus] in rationall numbers, utterly excluding all mention or thought of Surds, and thinks that if Longomontanus cannot understand y^t paper he can understand nothing.'

Cartesianism.[1] Salmasius, who was given an honorary professorship at Leyden University with no duties and a high salary, was one of the most eminent men in the faculty.[2] As a doyen of European literature in the 1640's and 1650's and a vigorous adherent of Cartesianism, Salmasius was the most influential academic consulted by Petty on Pell's behalf. His ready and whole-hearted support was a valuable asset in the battle against Longomontanus. In a personal way, Petty's meeting with de Laet was a most significant event, for this professor was one of seventeenth-century Holland's great early authors on political, economic and geographical natural history.[3] For example his De Imperio Magni Mogolis, perhaps the most accurate and comprehensive early account of India, was based on the systematic collection of eye-witness material, as well as thorough research into the literature then available about the sub-continent. Covering topics which included economic statistics, currency distribution and various weights and measures, this account was merely one out of a series on different countries and geographic areas composed by de Laet. Discussion with him over the next twelve months must surely have reinforced Petty's

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1. Franz Van Schooten, the elder (1581-1646) and Franz Van Schooten, the younger (c.1615-1661) were Professors of Mathematics at Leyden. Both ardent Cartesians, they provided formidable support for Descartes in his clash with Voetius. See Nieuw Nederlandsch Biografisch Woordenboek, (Leiden, 1911-1937), vii, 1108-1113 (hence-forward: N.B.W.)
2. For Salmasius (1596-1667) cf., A.Chalmers, The General Biographical Dictionary, (London, 1812-1817), xxvii, pp.72-78; N.B.W., v, 649-652.
3. For de Laet (1593-1649) see: The Topography of the Mogul Empire as Known to the Dutch, ed., and trans., by E.Lethbridge, (Calcutta, 1871) pp.1-3; The Empire of the Great Mogol, A Translation of De Laet's "Description of India and Fragment of Indian History", trans., J.S.Hoyland, ed., S.N.Banerjee (Bombay, 1928), pp.iii-vi. De Laet's publications reflect the rapid growth of the Dutch commercial empire. Cf. D.W.Davies, A Primer of Dutch Seventeenth Century Overseas Trade (The Hague, 1961).

previous training and interest in 'geographical' subjects and can therefore be regarded as a seminal influence on his later concept of 'Political Arithmetic'. Another important figure was Jacob Gool, an outstanding orientalist, Cartesian, Professor of Mathematics, founder of the University Observatory, and universal scholar.[1] In Petty's letter to Pell, Gool appears as the first, and most extensively reported commentator, which suggests that here was another senior figure who was happy to patronise the young Englishman. Again, this was a personal contact which, even if it remained at the didactic level, would have been important to Petty's developing knowledge of continental natural philosophy. The last person in Leyden who at this stage received a copy of Pell's tract from the young medical student was Joncker Hooghland, 'a Chymist and Physician, de Cartes his most intimate freind and Correspondent, who has promised at his next writing to send one to de Cartes.'[2]

The two subsequent letters that passed between John Pell and William Petty indicate that the latter's occupation as literary factor for his older colleague was soon carried one stage further.[3] As well as taking copies to several other Leyden residents, Petty also arranged for

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1. For Gool (1596-1667) see, J.P.Vogel, 'The Contribution of the University of Leyden to Oriental Research', Art and Letters: Royal India and Pakistan Society, 23 (1949), 45-47; A.Chalmers, General Biographical Dictionary, op.cit., xvi, pp.82-86; N.B.W., X, 287-289; W. de Sitter, Short History of the Observatory of the University at Leiden, 1633-1933, (Haarlem, 1933); Gool taught engineering in the school founded by Stevin at Leyden University.
2. Petty to Pell, Brit. Mus. Sloane MSS. 4279, f.184. For Horghland, or Hoghelande, see Descartes Correspondance, ed. C.Adam and G.Milhaud (Paris, vols. 1-8, 1936-1963), iv, 141, 211.
3. Letter, Pell to Petty, Brit. Mus. Sloane MSS. 4280, f.204, r + v, dated 3 August [1644], Amsterdam to Leyden. Petty's reply, dated 8 September, 1644, is at Brit. Mus. Sloane MSS. 4279, f.185, and a copy is printed in Fitzmaurice, Life, pp.9-10.

delivery of the treatise to 'MR Oughtred, [and] MR Barlow', two leading mathematicians in England. It is this offer, and Pell's subsequent statement that: ' ... I shall not send any to MR Oughtred nor MR Barlow, supposing y^{t} You will doe it & y^{t} you know surer addresses to that purpose then I doe,'[1] which suggests that Petty had already benefited from an association with Oughtred before coming to Holland in late 1643. In the same letter Pell also expressed his gratitude for Petty's previous efforts, explained that Descartes would probably see copies already despatched to 'Monsieur Hardy' in Paris, and commented:

> 'I have beene persuaded y^{t} Dr Kyper beares me a little ill-will, I thinke he knowes not why, and perhaps it is not true. I shall desire that Spanheimus may have one with the first opportunity to whom I pray present my best respects, as to one whom I take to be my Cordiall freind, at least as friendship goes now a dayes. Except he and Herbordus, I thinke none of the rest know so much of me as my name, unlesse ye noise made of me since I became Professor. You y^{t} [are] upon ye place may better discerne what professors ... deserve not to be passed by, either for your understanding in these things or for their goodwill to You or Me. For such, I shall send you coppies, were they an hundred.' 2

In his brief reply Petty told Pell that he had followed his further instructions to the letter, though owing to the 'troublesome tymes', he could only send the tract to Oughtred and Barlow amongst his friends in England. Petty's response also establishes that Frederick Spanheim, Leyden's Professor of Theology,[3] Adriaan Heereboord, Professor of Logic[4] and ' ... Dr. Wybord, an Englishman and mathematician, with divers

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1. Brit. Mus. Sloane MSS., 4280. f.204 r.
2. Ibid., f.204 r + v.
3. Brit. Mus. Sloane MSS. 4279, f.185. For Spanheim (1600-1649) see Chalmers, General Biographical Dictionary, xxviii, pp.254-256; N.B.W., X, 953-954.
4. For Wybord or Wybard see below p.116.

others ...' were all supplied with copies of the refutation.

In the light of the foregoing evidence there can be no doubt about the impact of this stay in Holland on the evolution of Petty's natural philosophy. A symbiotic relationship with John Pell reinforced his successful efforts at integration with the vigorous academic and scientific communities in the city of Leyden. Although the effects of this integration must remain unclear, it would be foolish to underestimate their importance. Where specific evidence about his Dutch experience is available, particularly with regard to his later economic, social and medical views, its significance is fully confirmed. Moreover, by the time he left Holland to go to Paris in September or October 1645, Petty was ideally equipped to exploit the benefits offered by this other leading centre of continental natural philosophy.

(c) Paris and Continental Science, 1645-1646

It is clear from his letter to Pell of 8 November, 1645 that, upon arrival in Paris several weeks earlier, Petty quickly capitalised on the introduction to Thomas Hobbes that Pell had thoughtfully provided:

> 'Sir,
>
> Father Mersen his desire to convey this enclosed to you serves me for an happie occasion, to express my thankfulnes for ye good of that acquaintance with MR Hobs, which your letters procured mee for by his means, My Lord of Newcastle and your good friend Sr Charles Ca[ve]ndish have been pleased to take notice of mee; and by his meanes also I became acquainted with Father Mersen (a man who seems to mee not in any meane degree to esteeme you and your works, and who wishes your studies may ever succeede happily, hoping (as others also doe) that ye world shall receive light and benefitt by them.) Sr I desire you not to conceive that any neglect or forgetfulnes hath caused my long silence, for ye often speech I

> have of you either with Sir Charles, MR Hobs and Father Mersen (besides ye Courtesy I recyved from you) makes mee sufficiently to remember you.' 1

This rapid penetration to the heart of French scientific circles was primarily due to Pell's links with the same world, and to Petty's outstanding mental and personal qualities. The Parisian experience was of great significance to the young natural philosopher's intellectual development, for it guided him towards a mental awareness, which established the priorities and criteria governing his future career. Indeed, it was this process that led to the brief duration of Petty's stay. Only nine months later, Sir Charles Cavendish wrote to Pell that:

> 'I am ashamed to trouble you so often, and not doe you the Service which I would for I can not now send you Monsr. Palliers Christian name as I promised to doe, but my agents failed me, and MR. Petit whom I most relied on, is gone for England, so that I dare not now promise anie more ...' 2

Despite the brevity of this sojourn in Paris, there can be no doubt of its value to Petty's burgeoning knowledge of continental science.

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1. Letter, Petty to Pell, Paris to Amsterdam, 8 November, 1645 at Brit. Mus. Sloane MSS. 4279, f.183; printed in J.O.H.Phillipps, A Collection of Letters, op.cit., pp.90-91. Copies of other letters to Paris, Brit. Mus. Sloane MSS, 4280 f.115v-f116r, show that Pell intended to give Petty an introduction to Cavendish, but was pre-empted by Petty's speed of contact: 'I perceive you have been pleased to take notice of Mr Petty. I hope you find him [a hopefull young man] not unworthy of wise men's counsell and countenance ...' ibid, f.115v. The brackets denote a passage deleted by Pell in his copy-letter.
2. Letter Cavendish to Pell, 7 June, 1646, Paris-Amsterdam, at Brit. Mus. Sloane MSS. 4278, f.257 r.

Petty's Discourse of Duplicate Proportion makes it abundantly clear that enquiries by leading scientists in Paris during this period left a profound mark on his lifelong attitude to mathematics, theoretical physics, Galilean mechanics and the experimental investigation of dynamics.[1] This debt was acknowledged by Petty at the beginning of the Discourse when he mentioned the early tutelage of Sir Charles Cavendish, Hobbes, Mersenne, Descartes, and Gassendi in his dedication of the work to William Cavendish, Duke of Newcastle.[2] However, Petty's honest discussion in the treatise also underlines the fact that he failed, both in 1646 and 1674, to make any major contribution to progress in these fields. As subsequent analysis of the problem shows, the importance of these nine months lay in Petty's unique chance to savour the full breadth and force of the continent's most brilliant scientific community.[3] For Mersenne's intellectual catalysis, just before his death, the presence and competition of major figures like Hobbes, Descartes, Mydorge, Roberval and Gassendi, and the fervent interest of minor English natural philosophers like the two Cavendish brothers, helped to make 1645-1646 one of the high points of French scientific activity during the seventeenth century.

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1. For a full analysis of these topics with regard to Petty and The Discourse, see Chapter 3, below.
2. This dedication is quoted p. 274 below.
3. See R.Lenoble, Mersenne ou la Naissance du Mecanisme, (Paris, 1943); H.M.Solomon, Public Welfare, Science and Propaganda in Seventeenth Century France: The Innovations of Theophraste Renaudot, (Princeton, 1972); Harcourt Brown, Scientific Organisations in Seventeenth Century France (1620-1680), (New York, 1934, re-issued 1967), especially pp.41-65; J.Jacquot, 'Sir Charles Cavendish and his Learned Friends' op.cit., especially 21-25 and 176-186.

The area with which Petty had the closest contact, however, was the intense debate over optics and the improvement of optical instruments. Petty's involvement with this subject sprang from his role as acolyte and amanuensis to Thomas Hobbes, who in 1645-6 was composing and perfecting his great manuscript work.[1] Petty's responsibility for the elegant transcription of the treatise, (the entire text of which is in his handwriting), is confirmed by a letter from Sir Charles Cavendish to Pell, dated November 1645:

> 'Mr. Hobbes intends to publish as soon as he can a treatise of opticks he hath done half of it and MR Petit hath writ it faire. It is in English at my brother's request.' 2

Petty did not, however, merely transcribe Hobbes' ideas: instead, as Aubrey later reported, he applied his skills to a joint study of comparative anatomy:

> 'His acquaintance began at Paris, 1648 or 1649, at which time MR Hobbes studied Vesalius' Anatomy, and Sir William with him. He then assisted MR Hobbes in draweing his Schemes for his booke of optiques, for he had a very fine hand in these dayes for draweing, which draughts MR Hobbes did much commend. His facultie in this kind conciliated them the sooner to the familiarity of our common friend.' 3

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1. 'A Minute or first Draught of the Optiques In two parts: The first of Illumination, The Second of Vision by Thomas Hobbes at Paris, 1646' at Brit. Mus. Harley MSS. 3360. Comparison between handwriting in this treatise and Petty's letter to Pell at Brit. Mus. Sloane MSS. 4279, f.183, shows that he transcribed the entire work. For Hobbes's scientific and optical theories see, F.Brandt, Thomas Hobbes' Mechanical Conception of Nature (London and Copenhagen, 1928) especially pp.166-216; M.M.Goldsmith, Hobbes and the Science of Politics, (Columbia, U.P., New York, London, 1966) especially 15-42; J.Jacquot, op.cit., 18-21, 24-27.
2. Cavendish to Pell, Paris to Amsterdam, 1/11 November 1645 at Brit. Mus. Sloane MSS. 4278, f.223.
3. Aubrey, Brief Lives, i, 367-368.

Therefore, while not responsible for any of the complex optical arguments adduced by Hobbes in the treatise, Petty was not restricted to the subordinate position of a mere secretary. Instead, his role was similar to that of Christopher Wren fifteen years later, when he prepared many of the plates for Robert Hooke's Micrographia.[1]

Optics was of crucial significance during this stage in continental science when the limitation and potentiality of early instruments was beginning to appear. However, some natural philosophers believed that to improve such devices it was necessary to abandon unsystematic, ad-hoc experimentation. Instead, they regarded theoretical progress as a prerequisite for the solution of practical problems. Furthermore, their corresponding analysis of light, vision, perception and instrumentation raised a whole range of complex problems in more generalised biology and physics.[2] Optics could also be considered, especially with regard to refraction and reflection, in a mathematical fashion, so that light and colour, instead of being treated as qualities, could be described in purely quantitative, or geometric terms. For all these reasons optics attracted intense interest during the 1630s and 1640s. It became a favoured subject which, owing to the inherent clarity of its 'geometrical' development, allowed easy comparison and debate on concepts in physics.

In France a commanding lead in this field was established by Des-

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1. R.Hooke, Micrographia or some Physiological Descriptions of Minute Bodies ... (London, 1665) 'The Preface', Sig. g.2. r + v; cf. A.R. Hall, From Galileo to Newton, 1630-1720, (London, Fontana ed., 1970) p.168. The plates in Micrographia between pp.60-61 and 92-93 should be compared with those by Petty in Harley MSS. 3360.
2. This analysis raised epistemological problems that are relevant today. See R.Tsien, 'Biological Variations on Themes by Descartes', in Essays Presented to C.M.Bowra, (Oxford, 1970) pp.74-87, for a penetrating review of these still unanswered issues.

cartes in 1637 when he published La Dioptrique.[1] This essay, probably Descartes' most brilliant piece of experimental research, primarily aimed at solving the practical problem of constructing a telescope on scientific principles. As one of the essays attached to his Discours de la Methode it was also designed to exhibit the ideal combination of abstract and experimental methodology. In a logical sequence Descartes analysed the nature of light, and then gave a geometrical account of the laws of refraction and reflection. From this he moved to a scientific description of the telescope and microscope, calculating, from a theoretical basis, the correct curvature of lenses. Within the main body of the essay, Descartes devoted five sections to an analysis of human vision, both normal and pathological, in which he exhibited an impressive knowledge of anatomy, which was itself the product of diligent research. In the eighth and ninth sections he produced a synthesis of the two preceding streams of argument to show that lenses used in the construction of a telescope must be hyperbolas and ellipses. To allow the practical instrument maker a chance of implementing these theories he concluded the essay with a detailed analysis of these curves, and a description, verbal and pictorial, of the best method and equipment for cutting lenses. Despite unforeseen technical problems, which limited the utility of the work, La Dioptrique can be considered one of the best examples of experimental and theoretical enquiry in the early

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1. R.Descartes, Discourse de la Mesode ... plus la Dioptrique ... (Leyden, 1637). Reference has been made throughout to this edition, in which la Dioptrique is separately paginated. For Descartes' work in optics, see, A.C.Crombie, 'Some Aspects of Descartes' Attitude to Hypothesis and Experiment' Actes du 2eme Symposium International d'Histoire des Sciences (Pise-Vinci 16-19 Juin 1958), Vol.11 de la Collection des Travaux de l'Academie Internationale d'Histoire des Sciences, (Paris, 1960), 192-201, especially 199-201; J.F.Scott, The Scientific Work of Descartes, op.cit., pp.27-51, 'La Dioptrique'; A.I.Sabra, Theories of Light from Descartes to Newton, (London, 1967) pp.17-135; A.C.Crombie, 'The Mechanistic Hypothesis and the Scientific Study of Vision: Some Optical Ideas as a Background to the Invention of the Microscope' in: Historical Aspects of Microscopy, ed., S.Bradbury and G.L'E.Turner (Cambridge, 1967) pp.63-86.

seventeenth century.

For his part, Hobbes was angered and embittered by what he felt was Descartes' untimely pre-emption of his own conceptual attitude to natural philosophy.[1] Until the last few years of his rival's life, Hobbes maintained a stony opposition toward the works and theories of Descartes, not only on the grounds that by publication of the Discours and Principia his scientific ideas had been unjustly forestalled, but also because of profound differences over fundamental concepts in physics, theology, psychology, mathematics and metaphysics.[2] For reasons, therefore, of similarity and dissimilarity, in 1645 and 1646 Hobbes was envious and resentful of Descartes' pre-eminence, and looked for ways of reducing his opponent's reputation and, conversely, of increasing his own.[3] As a result he decided to expedite publication of a treatise on optics which, due to the subject and his extensive expertise, would exhibit the superiority of his own system and scientific method over that of his rival. Such economy of effort appealed strongly to Hobbes. Consequently, he put aside his work on De Corpore and, with the help of his young amanuensis, pushed ahead with the composition of his optical treatise. The result was impressive.

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1. Cf. J.Jacquot, 'Sir Charles Cavendish...' op.cit., 73, 76-79, 81-85. In a letter to Pell, 1/11 May, 1645, at Brit. Mus. Sloane MSS. 4278, f.205, Cavendish says ... 'MR Hobbes is so avers from a friendship with Mr: de Cartes that he would not see him when he was heere'.
2. Compare the rival systems of Hobbes and Descartes as described in Brandt, Thomas Hobbes, op.cit., and E.J.Dijksterhuis, The Mechanisation of the World Picture, trans., C.Dikshoorn (Oxford U.P. paperback, 1969) pp.403-418. In physics, Hobbes laid greater emphasis on motion, Descartes on extension. In 1646 Hobbes was an atomist who believed in vacua, Descartes a corpuscularian and plenist; in mathematics, Hobbes never mastered algebraic techniques, of which Descartes, in his 'universal mathematics', was a leading innovator. See below, Chapter 3, pp. 291, 329-331.
3. Brandt, op.cit., p.190. See also H.W.Jones, 'Essay Review : Thomas Hobbes, De Homine. Traite de l'Homme ... (Paris, 1974)' Brit. J. Hist. Sci., 8 (1975), 166-170, especially 167, and 168, n.5.

Composed as an answer to the Dioptrique, 'A Minute or first Draught of the Optiques' naturally followed the general schema established by its opposite number.[1] However, Hobbes' tract, over three hundred and fifty pages long, was much more substantial than its counterpart. Naturally, different emphases predominated. There was, therefore, far less discussion of the physiological transmission of light, and far greater analysis of its geometric properties in refraction, reflection and enlargement. As such the treatise clearly exhibited Hobbes' grasp of Euclidian geometry and Galilean mathematics, along with his outstanding mental acuity and wide erudition.[2] Furthermore, Hobbes, like Descartes, was clearly forced by the intrinsic character of the problem to forsake what was basically an a priori approach to science in favour of detailed experimentation with optical instruments, prisms, mirrors and other visual phenomena. This led him to say at the end of the treatise:

> 'Nor doe I feare that he attentive Reader will find, that which I have delivered concerning ye Opticques fitt to bee cast outt as Rubbish among the rest; If hee doe, he will reede from ye authoritie of Experience, which confirmeth all I have said.' [3]

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1. Brit. Mus. Harley MSS.3360 f.3 r. Hobbes made his opposition to the anonymous Descartes quite clear: 'By putting you in mind hereof, [ie. of light, caused by motion] I doe indeed call you to witnesse of it, because the same doctrine having beene since published, by another, I might else bee challenged for building on another mans ground. Yett philosophicall ground I take to bee of such a nature, that any man may build upon it that will, especially if the owner himselfe will not'.
2. For examples of this broad knowledge, see references to the optical work of Fabier, 'a Jesuite of Lyons', ibid, section 1, p.51 and the extended discussion of other inaccurate sources, including Vitellio, ibid, Section 2, pp.239-241.
3. ibid., Section 2, p.241.

Hobbes based his claim to accuracy on the 'authoritie of Experience', in this case detailed experimentation, rather than the clear and self-evident force of reason alone. Furthermore, he made reference to current experimental work of other natural philosophers where it supported his own arguments. For example, he quoted the corroborative research of Gassendi, his close friend and colleague:

> 'If therefore with an Instrument, you observe the true angle that 2 fixed stars in ye azymuth or verticall circle make att ye eye you shall find that ye visuall angle under which they are seene, when they are neere ye horizon is lesse, then ye visuall angle taken with the same Instrument, when they are removed towards ye Zenith ... And this Experiment hath beene made in divers stars at divers times and registered by the Observer himselfe mons^r Gassendi, who is so exact both in his skill and in his manners, as neither to be deceived nor to decyve.' 1

The theoretical physics on which Hobbes' detailed analysis of optical phenomena rested, was evident throughout the introduction and text of the treatise. At this stage in the evolution of his ideas Hobbes firmly believed that all natural phenomena depended on the mechanical reaction and interaction of discrete particles. Light was propagated by the alternating expansion and contraction of the optical source, which in turn emitted particles, thus creating an instant, particulate pressure that was transmitted to the eye through the medium of the air. The transmission of light through the eye, up the optical nerve and into the brain, worked on exactly the same principle of a mediumistic or mechanistic chain effect.

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1. ibid. Section 2, pp.184-185. See also A.G.Debus, 'Pierre Gassendi and his "Scientific Expedition" of 1640', Archives internationales d'histoire des Sciences, 16 (1963), 129-142, especially 140; O.R. Bloch, La Philosophie de Gassendi. Nominalisme, Materialisme et Metaphysique, (The Hague; 1971); The Selected Works of Pierre Cassendi. ed. and trans. by C.B.Brush (Johnson Reprint, N.Y. and London, 1972).

Therefore, the fundamental cause of illumination and visual perception was the motion of particles along straight lines, with each motion or action creating an equal counteraction. The behaviour of light, said Hobbes, was ... 'to bee considered without respect to the matter of ye object, or of the medium, (that is to say) as mathematicall quantity only'.[1] All optical phenomena could be described and analysed according to geometrical rules. This geometrization of optics, when linked with thorough experimental research, and a theory of physics which was entirely consistent under these conditions, revealed Hobbes, the practising scientist, at his most effective.

Although Petty could in general make only a slight contribution to Hobbes' erudition and scientific knowledge, he did, nonetheless, provide essential secretarial and practical services. In particular, he was responsible for the tract's detailed anatomical exposition, and for the excellent illustrations which constituted one of its central features. With regard to the short anatomical section which introduces the treatise, it is notable that the diagram of the transverse section of the eye is a direct combination of Cartesian and Vesalian descriptions of the same organ. Indeed, a careful inspection of the manuscript reveals that, to begin with, Petty and Hobbes followed the more inaccurate Vesalian representation, but, realising their mistake, subsequently pasted a copy of the Cartesian picture of the iris, pupil, lens, and cornea over the original drawing. Comparison of the three diagrams by Petty, Descartes and Vesalius therefore shows that Petty and Hobbes produced an essentially derivitive anatomical account, paying Descartes the high compliment of plagiarism. Furthermore,

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1. Brit. Mus. Harley MSS. 3360, Section 1, p.7.

there is no indication that the two colleagues had previously carried out their own corroborative dissection of the eye.[1] It is still certain, however, that Hobbes relied upon Petty's anatomical skill and his 'very fine hand ... for draweing' to complete and illustrate the physiological and geometrical diagrams on which the treatise depended.

Given the complexity of the debate over optics between Hobbes and Descartes, what were the benefits for Petty of his role as amanuensis? Firstly, he was given a thorough grounding in those areas of physics which currently experienced the most rapid and arresting progress. Many of his subsequent ideas about statics, mathematics, and the 'mechanical philosophy' were the direct result of this training. Secondly, whether aiding Hobbes in his research work, or just following arguments as he transcribed them, Petty absorbed not only a deep understanding of experimental procedure and some detailed scientific information, but also a realisation that all natural phenomena were amenable to scientific and mathematical analysis. Moreover, Hobbes' personal belief that 'ratiocination' could, and should be applied to social as well as natural phenomena, must surely have provided Petty with a new vision that complemented the social and economic awareness gained in Holland. As Hobbes himself claimed:

> '... if it [the optical theory] bee found true doctrine (though yett wanteth polishing) I shall deserve the Reputation of having beene ye first to lay the grounds of two Sciences, this of Optiques, ye most curious, and y^{t} other of naturall Justice, which I have done in my book de Cive, ye most profitable of all other'. 2

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1. The account in A.Wood, Athenae Oxonienses, iv, c.214, might suggest that they carried out some original anatomical research: 'he retired to Paris, studied anatomy, and read Vesalius with Hobbes ... who loved his company exceeding well, and was not wanting all occasions to forward his pregnant geny ...'
2. Brit. Mus. Harley MSS. 3360, Section 2, p.241.

Even with regard to verbal definition, which was the linguistic counterpart of geometric definition, and on which logical 'ratiocination' was based, we find that Petty's approach, relating back to the techniques of Suarez, was stimulated and confirmed by Hobbes's procedural commitment.[1]

Despite this educative experience and the outstanding stimulus of the scientific community in Paris, Petty still chose to leave the country after nine months. At first sight this decision must appear anomalous, for London simply could not compete with the French capital for certain types of scientific awareness and activity. To identify the reasons which lay behind Petty's choice, it is necessary to analyse the methodology and intent of 'continental' science as practised in Paris during 1645 and 1646.

While there is a danger that simple differentiation between French scientific rationalism, and English empiricism, will produce a misleading caricature, it is still necessary to search for points of dissimilarity along these lines. It is undeniable that in Paris the prime scientific emphasis lay more on the 'case-history' approach to aspects of physics, mathematics, and problems in epistemology and logic, than on the social and utilitarian role of science. This does not mean that these last considerations were not, for example, present

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1. See below, Chapter 3, p. 330 note 1. See also Petty Papers, i, 149-166, 'Dictionary', where a number of Petty's definitive exercises are reproduced.

in the minds of Mersenne, Descartes, Roberval or indeed Galileo,[1] but rather that the practical application of their work was consequent upon their initial enthusiasm for scientific problems and philosophic systems per se. In England, however, the motivation and interest of many reformers and Baconians depended first on the potential of various sciences for social amelioration. Only then did the intrinsic interest of particular problems, and the certainty and satisfaction to be derived from complete philsophical systems assume importance. This difference of emphasis was crystallised in Petty's extreme statement of English Baconianism several years later, in his argument with Henry More over Cartesianism and correct scientific procedure. Furthermore, in 1645 this fundamental, and almost subrational support for induction and utilitarianism was strengthened in Petty's case by his burning desire for self-advancement, which appeared to be more easily attainable in England, after the end of the Civil War, than in France. Petty's conclusion was that practical, scientific achievement at home would produce tangible rewards for the scientist. All these reasons help to explain why the young

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1. The dangers of over-simplification and the corrective needed to redress the balance is analysed in H.Brown, 'The Utilitarian Motive in the Age of Descartes'. Ann. Sci.,1 (1936), 182-192. For later practical concerns at the Academie des Sciences see A.J. George, 'The Genesis of the Academie [des] Sciences', Ann. Sci., 3 (1938), 387-388 and passim. For Roberval's interests, see H.M. Walker, 'An unpublished hydraulic experiment of Roberval' Osiris, 1 (1936) 726-732. For the French attitude to Bacon c.1630-1640 cf. H.M.Solomon, Renaudot, op.cit., pp.74-75, and for Mersenne's critical view of what he regarded as the naive inductivism of Bacon, Le Noble, Mersenne, op.cit., pp.329-335. For Galileo and the utilitarian motive cf. L.White, 'Pumps and Pendula: Galileo and Technology' in, Galileo Reappraised, ed., C.L.Golino (Los Angeles, 1966), pp.96-110. See also A.R.Hall, Galileo to Newton, op.cit., p.148, for Huygens' later support for Baconian natural history.

natural philosopher left France and returned to England in May 1646.[1] However, despite this motivation and his personal attitude towards scientific methodology, he was still deeply indebted to his Parisian training. For it was this involvement with the method and content of French science which gave Petty the mathematical and methodological tools that later helped him to fuse empiricism with a sophisticated scientific rationale. Indeed, whether in the less notable Discourse of Duplicate Proportion, or his outstanding development of political arithmetic, Petty subsequently presented a unique approach to natural philosophy which was, in part, a direct synthesis of this early experience and training.

(d) London : Invention, Education and Reform, 1646-1650

When he returned to England in the summer of 1646, Petty faced a most uncertain future. A young man of low social origin, and few important contacts, he could rely only on innate talent, and a driving ambition, to achieve professional and intellectual success. However, despite the grievous economic disruption and widespread poverty experienced by England in the aftermath of the Civil War, the picture was not entirely negative.[2] Partially as a result of this economic

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1. For an assessment of Petty's subsequent attitude to Pascal, as an alternative exemplar of French scientific and philosophical procedures c.f. M.Vamos, 'A Note on Petty, Pepys and Pascal', French Studies, 22 (1968), 302-306. See also A.W.S.Baird, 'Pascal's Idea of Nature' Isis, 61 (1970), 297-320.
2. For contrasting, but consistent evidence on this dislocation, and the economy's latent potential, see M.H.James, Social Problems and Policy during the Puritan Revolution, (London, reissued 1966) pp.35-66; C.Wilson, England's Apprenticeship, 1603-1763, (London, 1967) pp.3-140, especially p.125, 'In retrospect, one can see all the indications that England was preparing for another economic step forward. But to contemporaries, these were generally times of stagnation and poverty'.

and social disruption, and partially as a response to problems which it caused, there was rapid change in the outlook of some influential groups, and in the minds of those who controlled the mechanisms of government.[1] New administrational and political realities demanded fresh policies and large numbers of competent public servants to implement them. The decline of old industries, and the early development of new patterns in agriculture, trade and manufacture allied with growing economic competition on a national basis, meant that those who possessed appropriate technical skills might also hope for rapid promotion and large financial rewards.[2] Viewed in this light, and given the personal attitude to natural philosophy, economics and government which he fostered during these years, Petty's return to England was a shrewd move. Though intellectually stimulating, the rarified atmosphere of exile in Paris failed to provide an opportunity for self-advancement equal to London's febrile, but potentially more rewarding climate. This was particularly true for Petty, whose maturing, Baconian view of science was acceptable to many of England's new intellectual leaders. Nonetheless, despite prodigious talents, the young natural philosopher found that tangible recognition of his virtuosity lay at the end of a long, and difficult road.

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1. Cf. G.E.Aylmer, The State's Servants, The Civil Service of the English Republic, 1649-1660, (London, 1973), pp.8-17 and p.339: 'On the whole, bureaucracies seem to have grown even faster in the aftermath of civil war and revolution than under any other conditions except those of modern "total" war'.
2. For some of these economic and social changes see J.U.Nef 'The progress of technology and the growth of large scale industry, 1540-1640'. Econ. Hist. Rev. 5 (1934), 3-24; F.J.Fisher 'The development of the London food market, 1540-1640', ibid, 5 (1935), 46-64; A. and N.Clow 'The Timber Famine and the Development of Technology'. Ann. Sci., 12 (1956), 85-102; C.M.Cipolla, Guns and Sails in the Early Phase of European Expansion, 1400-1700. (London, 1965), especially pp.72-89.

Petty's immediate movements on arrival in England, and his subsequent travels during the next three and a half years, are not easy to document. After a brief stay in Romsey,[1] he probably came to London to investigate the most promising avenue for his future career. Fragments contained in his medical manuscripts[2] indicate that in 1646 and 1647 he journeyed to towns like Oxford, Reading and Bath, working as an itinerant doctor, to locate the best area for a new practice. If these medical notes are not misleading, they suggest that he was, for more than a year, uncertain about the best course of action. This uncertainty, however, was slowly replaced by more definite plans as his understanding of current circumstances and his relationship with Samuel Hartlib and his circle, began to develop.

The first reference to Petty in the reformer's voluminous correspondence comes in a letter which the politician, Sir Cheney Culpeper, sent to Hartlib in March, 1647.[3] There is no indication as to when Petty first met Hartlib, or how the meeting took place, though it would not be surprising if Pell once again provided this important personal connection. Whatever the circumstance, this contact proved to be one of the most important in the young natural philosopher's life. In

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1. Fitzmaurice, Life, op.cit., 'Will', p.319.
2. B.H. MSS. Volume 3, (Medical Studies) no.17, fragment of a medical diary, paginated 1-4; p.3. refers to 'Mr. Wilgoose of Oxford', p.4, to 'Mrs Jamison of Reading', and p.2 to 'The Wife of Thomas Beacon of Bathe, May 1647, [who] had a great yndolent tumor of one side of her belly ...'. Petty's brief visit to Oxford in 1647, and possibly in 1649, may explain why Aubrey noted 'Dr Petty was resident in Oxon, 1648, 1649 and left it (if A.W[ood] is not mistaken) in 1652'. cf. Keynes, Bibliography, p.37. These medical notes do not clarify whether Petty recorded them concurrently, or at a later date.
3. Hartlib Papers, xiii, 169, f1v, letter dated 11 March, 1647. Culpeper discussed Petty's help as a translator. Although Culpeper's letter to Hartlib, at Hartlib Papers, viii, 31, f1r-2v, appears to be dated either 'Jan. 25, 1647' or 'Jun.25, 1647' it is more likely, given the contents, that it was written in June rather than January.

1647 Hartlib was at the epicentre of a powerful movement, which sent shock waves through English intellectual circles with demands for the fundamental reform of society. This was to be achieved by new educational programmes, the development of new agricultural and industrial technology, the rationalisation of central economic and governmental functions, and the establishment of religious tolerance and understanding within the community.[1] Hartlib's network of personal contacts, and those of close friends such as Dury, Haak, Comenius and Pell, covered a wide range of personalities and professions relevant to the central purpose of reform.[2] The detailed chronicle of their relationship shows that Petty's sudden arrival in London in 1647 was particularly appropriate, for it was then that Hartlib and his colleagues were willing to assist Petty, and others like him, with their careers. At the same time they provided ideas and contacts which drew them in to the all important work of reform.

After the dismal events of the previous four years, when Hartlib's earlier plans seemed lost and a large diaspora of his supporters had taken place, there was a strong sense of hope and a growing belief that 1646 would see the beginning of a new era of reform.[3] Consequently, Hartlib and Dury published plans for a new agency which would direct and develop various areas of national life, in which this fundamental

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1. For basic sources on Hartlib see: C.Webster, The Great Instauration, Science, Medicine and Reform, 1626-1660 (London, 1975) henceforward, Webster: Instauration; idem, Samuel Hartlib and the Advancement of Learning, (Cambridge, 1970), pp.1-72, henceforward, Webster: Advancement; G.H.Turnbull, Hartlib, Dury and Comenius, Gleanings from Hartlib's Papers, (London, 1947) henceforward, Turnbull: H.D.C.; H.R.Trevor-Roper, 'The Three Foreigners: The Philosophers of the Puritan Revolution', in Religion, The Reformation and Social Change (London, 1967), pp.237-293.
2. For their similarity as communicators, see the early essay by D. Stimson, 'Hartlib, Haak and Oldenburg: Intelligencers', Isis, 31 (1940), 309-326. For Dury cf. T.H.H.Rae, John Dury, Reformer of Education, (Marburg, Lahn, 1970); for Haak cf. P.R.Barnett, Theodore Haak, op.cit.
3. Cf. Webster, Advancement, p.43.

reorientation would take place. Known originally as the Office of Address, with two sub-divisions called the Office for Communications and the Office for Accommodations, the institution was designed as the central corporation which, with government backing and under the direction of the two reformers, could organise this basic restructuring of society.[1] In a ferment of activity Hartlib and Dury stimulated acquaintances, old and new, to produce suggestions for detailed reform in specific areas of education, agricultural and industrial technique, economic organisation, and governmental legislation. The hypothetical institutions which they envisaged underwent a rapid process of evolution, as new ideas, new political situations, and new people, provided stimuli for change and re-consideration. In every area, Hartlib and Dury drew in 'hopeful' new figures, who might contribute to the success of their plans. In doing so, they engrossed the attentions and activities of an enormous range of more, or less, talented inventors, educationalists, politicians and technologists.[2]

One particularly notable act of recruitment was Hartlib's successful campaign to absorb the circle that, at the end of 1646, had developed round two outstanding young natural philosophers, Robert Boyle and Benjamin

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1. The design of the Office of Address first appeared in, Considerations Tending to the Happy Accomplishment of England's Reformation (London, 1647). This was produced under the aegis of Hartlib, and, though published anonymously, was written by Dury. See Webster, Advancement, pp.37-60 and 119-139. See also Webster, Instauration, pp.67-77.
2. A basic source for this throng of visitors to Hartlib are his L.S. Ephemerides, which are scattered throughout various bundles in the Hartlib Papers. For purposes of convenience Professor Turnbull's excellent type-written transcript, which is lodged with the Papers, has been utilised, and Hartlib's idiosyncratic pagination followed throughout.

Worsley.[1] This group, which overcame geographical separation and maintained its identity through correspondence, was known to its members as the 'Invisible College'. The exact nature of this informal society, and its detailed relationship with Lady Ranelagh's circle, Hartlib's agency, and the famous '1645' group of Wallis, has only recently been established. Clear identification has enabled a far more interesting and consistent picture of the activities of natural philosophers in post Civil War London to emerge. In particular, this recent research enables the biographer to set Petty's vigorous efforts within a clear framework which elucidates and clarifies this crucial period in his early life. Having outlined the broad environmental factors he encountered when settling in London, it is now reasonable to proceed with an examination of Petty's maturing attitude towards natural philosophy, and the manner in which this attitude controlled his multifarious activities between 1647 and 1650.

As might be expected, the general axis of Petty's intellectual development lay towards the combination of experimental and utilitarian science in a Baconian mould, with the exploitation of opportunities that would lead to personal and financial success. Therefore, when jotting down his plans, in a way which typified his approach to personal or intellectual problems, Petty left a most illuminating synopsis of his aims and intentions during these years:

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1. For identification of the 'Invisible College' and Boyle's early relationship with Hartlib, cf. C.Webster, 'New Light on the Invisible College: The Social Relations of English Science in the Mid-Seventeenth Century' Trans. Roy. Hist. Soc., 5th Series, 24 (1974), 19-42, henceforward, Webster, 'New Light'.

'1. By procuring priviledges for publique designs of Universall use.
2. By making modells and directing for private works and engines.
3. By selling some works made by myself and friends.
4. By giving, selling transcripts of such artifices truly but not fully and plainely related.
5. By printing the same afterwards.
6. By drawing in adventurers upon the credit of former performances.
7. By employing, obliging all artists severally apart and some with mee to assist.
8. By honorary pensions from great persons.
[9. By the practice of Physicke (setting up and maintaining a Nosocomium Academicum]

To maintaine Servants.

1. By transcribing translating drawing etc. my Communications.
2. By showing rarityes to the curious'. 1

This broad programme for the invention and commercial development of new machinery, and new engineering techniques, with its strong underlying sense of self-advertisement and self-advancement, was one which Petty pursued with almost unreasoning determination between 1647 and 1649. Such aims seem antithetical to those scientific problems, and procedures, current in Paris when Petty was there two years earlier. Instead, they relate far more closely to his preceding experience in Holland, with its advanced industrial technology and rationalised economy. Above all, they were a product of Petty's intelligent appreciation of the forces operative within the English economy and London's reformist groups, in the years immediately following the first civil war.

However, this utilitarian bias did not exist in a vacuum, unsupported by any theoretical or rational apparatus. On the contrary, the debate which Hartlib stimulated between Henry More and William Petty during the winter of 1648 to 1649, reveals a clear appreciation on the part of both proponents, that there was a wide choice of methodological

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1. B.H. MSS. Volume 3, no.2, v. The square brackets enclosing item 9 denote the fact that Petty added this (as an afterthought) to the top of the original ms.

procedures open to them, and an equally clear understanding that they represented two opposing attitudes towards the role, and function, of contemporary natural philosophy.[1] The statement of these opinions is all the more important in Petty's case, because, throughout his life, he was often reticent about his own methodological and epistemological preconceptions. Unlike Boyle, Ray, Descartes, and Henry More himself, Petty was scrupulous in restricting his contribution to debates on methodology, which he felt were inherently unproductive. This attitude was composed, partly from a lack of sympathy for abstract rationalisation, partly from a lack of sensitivity and sophistication, partly from an unflinching adherence to the empirical pragmatism of his own Baconian principles, and partly from a preference for fact rather than opinion. However, in the light of the evidence contained in this highly significant correspondence, and of his wide experience of contemporary natural philosophy on the continent, it is clear that Petty had arrived at these conclusions on the basis of well-informed judgment, rather than simple prejudice or ignorance.

The exchange between More and Petty was initiated at the end of 1647, when Hartlib, constantly looking for supporters to bolster his plans for reform, contacted the Cambridge scholar. Encouraged by Hartlib and Cudworth to correspond directly with Descartes, who was then the overriding influence on his scientific attitudes, More eventually wrote (via Hartlib) to the great French philosopher, in December 1648. In the covering letter, which was sent to his colleague in London, the Cambridge Platonist heaped praise upon Descartes. Having lauded 'this

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1. For an exemplary discussion of this correspondence, with copies of the letters between More and Petty cf., C.Webster, 'Henry More and Descartes: Some New Sources', Brit. J. Hist. Sci., 4 (1969), 359-377, henceforward Webster, 'More and Descartes'. For the complete text of Petty's reply see below.

noble Spirit', who had published 'those precious and incomparable bookes of naturall philosophy', most notably his Specimina,[1] More went on to enshrine Descartes' personal talents, his scientific methodology, and the validity of his ideas, in a welter of fulsome prose:

> This man certainly is the very Miracle of the world, as such an one that Nature has done her utmost artifice in framing his temper and fitnesse for so brave designes as he hitherto has been prosequuting and dos still judiciously and cheerfully prosequute, and I question not but with admirable success ... Those eminent partes which Nature, and that but frugally too, bestows singly on severall, are in him united together in one and that in the highest degree, viz. largenesse and amplitude of apprehension and phansy, quicknesse and penetrancy of witt, fixednesse of animadversion, close and subtill deduction of reason, and for a sure foundation of all, a patient condescent, and unwearyed toyling in all manner of usefull experiments, for the discovery of Nature. Which last as it is most necessary, especially for the matters concerning the better accommodations for health, ease and pleasure, so far that higher and nobler and enriching our mindes with the most assured knowledge of God and nature, is very ineffectuall, without the superintendency and assistancy of those more raysed faculties aforementioned, but men may dig and droyle like blinde molewarpes in the earth, and yett never be able to emerge in dies luminis orae, but ly dead and buryed in an heap and rabble of slibber sauce experimentes, that are to little more purpose then what able wives, marriners, or Mechanicks are able to apply them to. And yett it would make a dog laugh, to think, how highly these low Spiritts, commonly conceited of themselves, and are more easily proud and conteemptuous then those, of far higher and more enlarged facultyes.
>
> But this gallent Spiritt Des Cartes, being so fully furnished with those higher endowments, has been of that perpicacity, as that he has been able, as they say, to spy light at a very little hole, and upon a few sure, and yet very cheape, experimentes (even such as no man that has been mayster of his five sences any considerable time in this world, has not had the happ to experiment himself, or to see others experiment them) has raysed such a graine of naturall Philosophy, for strength so

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1. More was referring to the Latin edition of the Discours, viz: Renati Des Cartes Specimina Philosophiae ... Dioptrice et Meteora ... (Amsterdam, 1644).

> impregnable, for beauty and comely complyance of one part with another so admirable, that costly expenses to this pretended end, that have been made hithertoo, compar'd with his successe, may seeme, misfortune or deceit. Truth is, I never found any account of Nature so sound and consistent as this of his is, nor ever hoped to meet with any thing this way of that perfection, whereof having no controversy with anything in his writings, that is essential to it, nor any obscuritys which I think I have not sufficiently mayster'd; nothing but satisfaction with your self, and my worthily honoured friend Mr. Cudworth, could have drawn me into this unsuitable employment". 1

Hartlib, while effective as a conduit for the early stage of the More-Descartes correspondence, was disappointed by More's lack of response to plans for social and educational reform, especially since the Cambridge Platonist intimated that he thought experimental, socially oriented science to be intellectually inferior. Hartlib obviously showed the letter to William Petty, who by then was deep in his confidence. More's comments, notably those relating to 'Slibber Sauce'[2] experiments, outraged Petty's sensibilities, primarily because it was concern for this type of scientific work that prompted him to leave Paris, and seek to develop technology which would be personally, and socially beneficial. The young inventor therefore composed a defence of elementary empirical procedure, couched in emphatically intemperate language. Because it states, with great clarity, fundamental views that characterised his position in 1648, and for the rest of his life, this letter will be quoted in full:

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1. Hartlib Papers, xviii, 1, ff.38v-39r.
2. The term 'slibber sauce', used in a medical and cosmetic context during this period, is defined by O.E.D. as 'A compound or concoction of a messy repulsive or nauseous character, used especially for medicinal purposes'. At this time Petty was working on new chemical drugs, dyes, and the preparation of anatomical exhibits.

'Mr. Petty's letter in answer to Mr. More'

'I place so much happiness in ye knowledge of Nature, that I am happy even to know that it is in others, though not in myselfe, and, doe therefore
[1] thanke you for ye Communication of Learned Mr. More his letter (wch I have translated into French) which panegyrick (considering his abilitie to judge) is to mee a very leading argument that Monsieur Des Cartes hath in perfection, that which I so much seeke and admire.

Monsieur des Cartes hath indeed made use of sensible principles such as are Matter, Locall Motion, Magnitude, figure, situation &c, so that when hee speakes, it is possible to understand that he meanes & therin hee is much to be prefer'd before the common schoole philosopher, who indeed have nothing else
[2] but words, & those such are not (according to the intention and end of them) the Images and Representatives of things, but words meereley chimarical signifying nothing, a language fitter to be used in another Imaginary phantasticall World, then in this reall one wherein wee are. 1

And out of these principles hee doth deduce soe Ingenious & well tuned hypotheses, that indeed hee solves the phaenomena of Nature by them much more
[3] probably and intelligibly, then can be done by the common way; hee is also accomplished even by his adversary & a most excellent Mathematician.

But yet I cannot think him so excellent a philosopher as Mr. More doth, nor in ye best way to be soe. For allthough hee may see much out witt other men as to see light at a lesser hole than they, yett I cannot beleeve his principles of Philosophy to be soe firme that stand upon such narrow feet as those few experiments mentioned in his works are; for it is not sufficient for Suppositions to bee accompted Axioms, when they only solve a few phenomena by the help of a strong witt to drive them on, but if they bee
[4] true, they must solve all equally well, & that soe easily, as that a meane capacity may bee able to foretell the effects of nature by them before they happen, and consequently produce great Noble pieces of art, tending to ye happiness of Mankind. And I believe that judicious Men vexed in Multitudes & vexieties of Experiments (though slibber sauce ones) may better see the defects or uselesnes of Descartes his philosophy then such as know noe more experiments, then what hee himselfe hath pickt out, and tells them off to verify his own Imaginations.

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1. For a discussion of one aspect of the Frenchman's work, which exemplifies this criticism by Petty, cf. R.Love, 'Revisions of Descartes' Matter Theory in Le Monde', Brit. J. Hist. Sci., 8 (1975), 127-137.

To bee sure I accompt him ye best philosopher I know most of, & is best acquainted with nature's Workes, & knoweth how to rule them in order to the provement of good help to Mankind, wherefore God made them. Now whether or noe or how much des Cartes his philosophy conduseth here unto, wee may know by sense (that sure though slow guide) by Inquiring how much ye Telescopes are mended, since the writing of his dioptickes whether any man can foretell the weather by his discourse of Meteors. Of what disease hath hee found out the certaine cure by his consideration of animalls; or what besides Notionall conjectures (though ingenious enough) hath hee produced: Or who, that hath followed his principles, hath drawne any new usefull or pleasant art or reall con-
[5] clusion from them. Till Monsieur des Cartes hath approved himself a philosopher in this Sense, I shall preferre Cornelius Drebbel [1] before him though he understood no Latin as one that hath done more though said less. I have wearied myself in running through Aristotles, Galens, Campanellas, Helmonts Paracelsus & des Cartes their Imaginary principles, and find much witt & phancy in them all (in some more & some lesse) and have beene highly taken with some of them, especially with those of Des Cartes, but doe now look upon the best of them, as Nut shells in comparison of the knowledge of the slibber sauce experiments I judiciously and selectly made, and I thinke that I better understand Nature now, than when I puzled myselfe in their Bookes, although I doe not as yet pretend to have found out Millions. [2]

Mee thinks it would make a dog laught to see Men that doe not know the things they talk and dispute so much about, when they see them, to thinke themselves better philosophers than such as experimentally know them, their operations one upon another, that are daily conversant in the works of nature, that doe diligently observe, compare & apply them, & produce wonderfull
[6] artifices by so doing, because they thinke that when the hand & senses are about experiments, that ye Reason and judgment are idle, if not extinct whereas they worke more effectually, as upon a better stock, then if they were employed in spinning the cobwebs out of bare suppositions & out of Principles, which though may be true, yet are remote abstracted & generall.

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1. Bacon was familiar with Drebbel's work, mentioning it in De Augmentis Scientiarum. For example, see The Philosophical Works of Francis Bacon, ed. J.M.Robertson, from the Ellis and Spedding texts, (London, 1905) p.508. Petty's arguments in paragraphs 5, 6 and especially 7, are a synopsis of sections from De Augmentis. Cf. Bacon : Works, pp.427-430, 500-511.
2. For an almost identical statement by another of Hartlib's close associates see the letters from Beale to Hartlib, c.1661, quoted in T.Birch, The Life of Robert Boyle, (London, 1744) pp.128-130.

I wish therefore that the great witts of these times could employ themselves in collecting & setting downe in a good order & Method all Lucifferous experiments & not bee too busy in making inferences from them till some volumes of that Nature are compiled, then wee should have a judge of the controversies; and when wee can finde such principles or axioms as will stand with all these experiments, they may as right bee accompted & admitted for such. In ye meane tyme they doe but hinder one another in wrangling each [7] against the others figments, whilst nothing certayne is produced by them all, either in theory or practice. And I pity ye universities, where many gallant witts spend themselves about words & bookes concerning things, but not about things themselves, who when they come about into ye world, doe perceive & lack knowledge. How comely their books did describe their subjects, & what pittifull people the Authors of them even themselves were, more then for language & Rhetorick.

If men tooke this Course, there would not bee so many bookes extant, for to write out a sheet of paper in describing often tryed experiments, would [8] prove a more tough piece of work than to scribble whole Realmes about frivulous conjectures & imaginations with controversies for and against them.

But lett men doe as they please. Experto credo Roberto (as ye saying goes) I saw ye non satisfaction of those wayes before I could loath doting upon them, & never knew any man who had once tasted the sweetness of experimentall knowledge, that ever afterward fasted after ye Vaporous garlick & onions of phantasmaticall seeming philosophy. Sir you have my opinion here upon and may have my self to bee

Yours

W.Petty' 1

The letter is entirely typical of Petty's attitude towards natural philosophy, though this underwent modification during his subsequent career. Not surprisingly, More reacted strongly to this outspoken rebuff. In his reply, dispatched to Hartlib on 12 March, 1649, the Cambridge scholar responded to all the counter-charges made by his

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1. Copy of Petty's original letter in Hartlib Papers, vii, 123, ff.1r-2r.

opponent. Careful reading of this reply indicates that More did hold a low opinion of chemical and mechanical experimentation, believing it to be irrational, and totally incapable of revealing the 'prima principia'. Furthermore, he thought that socially oriented science was concerned merely with improving the standard of life, rather than raising men's minds to the contemplation of eternal verities, and God's wisdom as revealed in Nature:

> 'But so far as I see Mr. Petty would measure the work of all Philosophy by what it can procure for ye back, bed and bord. Wee shall be a common wealth of rarely improved beastes, not of learned men, that shall know how to keep up and maintaine the low interest of our darling senses to a cows-thumb, excellent Artists' But the eternall light of God bear witness against blinded mankinde, that temperance and humility, from whence ariseth contentednesse, the very tree of life; or what other els there is of morall or divine virtue, is more for the health of man and the common good, than all that the witt of any mortalls can dig out for their own ease and welfare, though they would teare Natures gutts out, and see her very heart beat.' 1

On the other hand, said More, Descartes outlined principles and procedures that, far from being 'Imaginary', were entirely rational, and consonant with current levels of knowledge about Nature and the workings of the world. Petty's criticisms were unfair, since Descartes' detailed exposition on minerals, plants, and animals had not yet appeared. 'When that is perfected, perus'd and found useless in communem vitam', wrote More 'lett men complain then'. He then made several concluding, and in his own view, damning observations: if only existing knowledge could be correctly utilised, then much pointless duplication by contemporary

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1. The letter is located at Hartlib Papers xvii, 1, ff.2r-3v. A similar argument was directed against Petty and Molyneux nearly forty years later, by Dudley Loftus. Cf. K.T.Hoppen, The Common Scientist in the Seventeenth Century, A Study of the Dublin Philosophical Society, 1683-1708, (London, 1970) pp.159-166, especially p.164.

experimentalists would be avoided; Petty's attack on the universities was reprehensible and destructive; without systems of knowledge, organised according to rational principles, research would inevitably result in the construction of a tower of Babel; and, with a final barb against his opponent, More challenged him to match the success of the great Frenchman in devising equally valid scientific principles with which to discover the laws of nature:

> 'I conceive that if Mr. Petty should live twice the Age of an ordinarie man, and spend all his dayes in experiencing, he will never bring an instance against Des Cartes his principles of Light, of the Loadstone, of the Rainbow, of the Flux and Reflux of the sea &c. And therefore it had been better done, to have fallen upon his own work tending to such particular uses as himself best knowes, then to vilify that, that he has no reason to pretend himself able to confute.' 1

The exchange between More and Petty exemplifies the broad range of attitudes adopted by adherents to the 'new philosophy' in the seventeenth century. More's rational view relied upon Neo-Platonism and Cartesianism, Petty's belief in experiment on principles derived from experience, incorporated within a wider, theoretical framework of Baconianism. The debate between these two 'modernistic' natural philosophers, therefore, provides a microcosmic picture of the polarity between the experimental, and conceptual approaches to science. Owing to the inherent process of such debate, both proponents inevitably reached extreme positions. This situation belied their common understanding that the methods of Descartes and Bacon possessed complementary features, which made them jointly necessary for the development of effective scientific procedure.[2]

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1. Hartlib Papers, xvii, ff.2r-3v.
2. For a later example of Petty's response to this type of debate see Appendix 3, v, below, and Chapter 3, p. 321 where Petty is shown to have utilised Neo-Cartesian arguments.

The divergence between the methodological approach of Petty and More was directly related to the different motives behind each man's involvement with science. Briefly stated, Henry More's interest depended upon a theological motivation. This required that any acceptable doctrine of nature must agree with the principles of theology. The basic laws of nature, like these theological principles, were not ultimately susceptible to experimental investigation. This could only explain the more gross phenomena, that lay at the foot of mankind's hierarchy of rational perception.[1] Experiment seemed either irrelevant, or even misleading, in the search for fundamental laws. Furthermore, utilitarian benefits were outweighed by moral dangers which might result from abuse of such power in the hands of degenerates.

Petty's view of science was an almost complete antithesis to that of Henry More. The comprehensive statement contained in his letter presents an autobiographical account of his fundamental attitude to the method and purpose of science. While admiring many great practitioners and philosophers, especially Descartes, he castigates them for their inability to produce tangible results validating their hypothetical exercises. He also attacks the concept that fructiferous experiments could not produce luciferous insights into the working of nature. To succeed in both is the only guarantee that those scientific procedures and principles adopted by the researcher are true or successful. Rational consistency is no substitute for experimental tests of the predictive accuracy of scientific hypotheses. Petty repeated this belief whenever he discussed scientific method duri[illegible]

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1. More was close to Hobbes over the inability of experiment to validate fundamental scientific laws. Petty usually regarded such methodological niceties as pointless and misleading. For Hobbes's views see M.M.Goldsmith, op.cit., pp.40-42.

these early years. Thus, Hartlib reported in his Ephemerides:

> 'The common and verbal philosophies are of that nature that whosoever hath most witt will get the better of his adversarie, but real experimental learning is for truth, and whosoever can make out by visible experiment that which hee undertakes hee will evince that hee hath the truth. For all knowledge must bee brought before their true judges which are either demonstration or sense and experiment, the rest is meere wit or rhetorick. Id. [Petty]' 1

Petty emerges as a Baconian empiricist, but not, it must be stressed, as a Baconian whose understanding of scientific principle was restricted, unintelligent, or vulgar. On the contrary, he often criticised other inventors and practitioners for blindly following ad hoc, experimental developments, without some identifable rationale:

> 'Dr. Dolman hath invented a new art of dying of skarlet in more orient colours. Is very well acquainted with Petty which judges him to be too empirical and experimenting without philosophies ...' 2

The motivation which underpinned Petty's scientific activity was founded on a compelling vision of science's potential to revolutionise control over the environment. Overwhelming benefits would emerge if enthusiastic experimentation was pursued by well-informed natural philosophers. The results should, in turn, allow those of 'a meane capacity ... to foretell the effects of nature by them before they happen'. Excessive regard to speculative first principles, or far-ranging hypotheses, would simply lead to abstract, academic debates,

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1. Hartlib Papers, M.S. Ephemerides, 1649, B-C 3.
2. Ibid, E-F 6. Petty was echoing Bacon's words in Novum Organum, cf. Bacon, Works, pp.274-275.

remarkable only for their sterility and irrelevance to the human condition.

Petty was not alone as an advocate of this empirical, experimental approach to science, with its strong bias towards practical problems. One of the outstanding features of the brilliant young natural philosophers drawn into Hartlib's sphere of influence in the late 1640's was their common and continuing espousal of this attitude. Thus, Robert Boyle, after mature reflection twenty years later, expressed an opinion that closely paralleled Petty's basic ideas:

> 'For though that famous Distinction, introduced by the Lord Verulam, whereby Experiments are sorted into Luciferous and Fructiferous, may be (if rightly understood) of commendable Use; yet it would much mislead those that should so understand it, as if Fructiferous Experiments did so meerly advantage our interests, as not to promote our Knowledg; or the Experiments called Luciferous, did so barely enrich our Understandings, as to be no other waies useful. For though some Experiments may be fitly enough call'd Luciferous, and others Fructiferous, because the more obvious and immediate Effect of the One is to discover to us Physiological Truths, and of the other to enable us to perform something of Use to the Possessour; yet certainly there are few Fructiferous Experiments, which may not readily become Luciferous to the attentive Considerer of them'. 1

Benjamin Worsley,[2] another of Hartlib's proteges, put forward an almost identical view. In June 1643 he said in a letter:

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1. R.Boyle, Some Considerations Touching the Usefulnesse of Experimental Naturall Prilosophy, The Second Tome, containing the later Section of the Second Part, (Oxford, 1671), Essay 1, p.44. See also Bacon, Works, pp.510-511, for his earlier statement of these ideas in De Augmentis, and p.289, in Novum Organum.
2. For Worsley's biography see Webster, Instauration, pp.59-67; Webster, 'New Light' op.cit., 30-31, infra; G.E.Aylmer, The State's Servants, op.cit., pp.270-272, 416-417; T.C.Barnard, Commonwealth Ireland, pp.219-222.

> 'For humane knowledge I honour only that w^ch is ... immediately deduced from, or built upon Reall, and certayne Experiments; and those so many, as to make an infallible Universall; seeing according to ye schooles, science is not of particulars. All men therefore sedulous in Experiments I honour alike whether they be physicall or naturall, medicinall, Astronomicall, opticall or any way mechanicall, or Chymical; all knowledge carefully grounded upon these, being not only certaine, or Reall, but Usefull'. 1

Similar opinions were also voiced by Miles Symner in a letter to Sir Robert King (October, 1648) which was passed on to Samuel Hartlib. 'In all these studyes' wrote Symner 'my scope is for reall and experimentall learning. I abhor all those ventosities, froth and idle speculations of ye schooles'.[2]

There can be no doubt, therefore, of the important procedural and psychological influence exercised by Baconian empiricism on the rapid evolution of English natural philosophy, from 1645 until the end of the Interregnum. This statement does not deny the growing importance of Galilean, Cartesian, Neo-Platonic, Gassendian, or alchemical traditions of enquiry in the formation of the complex outlook of English science during the same period.[3] On the contrary, the later views of leading

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1. Hartlib Papers, viii, 27, ff4v-5r.
2. Symner's letter is at Brit. Mus. Sloane MSS. 427, f.85. A copy is at Hartlib Papers, xlvii, 6, f.1r + v. For Symner's career cf: T.C.Barnard, 'Miles Symner and the New Learning in Seventeenth-Century Ireland' J.Roy. Soc. Antiq. Irel., 102 (1972), 129-142.
3. For the influence of Helmontian, Gassendian and Cartesian ideas on Walter Charleton, a popularist of scientific ideas during the 1650s, see: L.Sharp, 'Walter Charleton's Early Life 1620-1659, and Relationship to Natural Philosophy in Mid-Seventeenth Century England' Ann. Sci., 30 (1973), 311-340, and Charleton, Physiologia Epicuro-Gassendo-Charltonia ... (London, 1654). See also the wide range of sources quoted during the Webster-Ward debate (1653-1654) in: A.G.Debus, Science and Education in the Seventeenth Century, The Webster-Ward Debate, (London, New York, 1970), passim.

natural philosophers such as Grew, Hooke, Wallis or Barrow,[1] merely confirm that they recognised the necessary relationship between such traditions, and drew on them to develop a more subtle and effective approach to scientific method and procedure. This analysis should not therefore be seen as a denigration of the outstanding efforts of continental scientists in the first half of the seventeenth century, nor as an attempt to minimise their undoubted influence on the development of English natural philosophy between 1650 and 1670.[2] Instead, early Baconianism and empiricism[3] should be regarded as dynamic, unifying factors, which

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1. Hooke's discussion of this methodological compatability, which benefited from the sophisticated debates between 1660 and 1680, is in 'Discourse of Earthquakes', The Posthumous Works of Robert Hooke, ed., R.Waller, (London, 1705), pp.329-331. See also, Anon., New Atlantis Begun by the Lord Verulam ... And Continued by R.H. Esquire ... (London, 1660), probably an undergraduate essay by Hooke. Cf. G.Keynes, A Bibliography of Dr. Robert Hooke, (Oxford, 1960), pp.2-4. For Barrow's views see: The Usefulness of Mathematical Learning ... Being Mathematical Lectures Read in the Publick Schools at ... Cambridge. By Isaac Barrow ... trans., and ed., J.Kirby (London, 1734), pp.58-61, 64, and p.133: 'The Foundation and Reason of Hypotheses ... is evident from Experience ... For nothing ought to be supposed, whereof we can make no Experiment, nor can illustrate or confirm it by some apposite Example: since the Possibility of an Hypothesis can be shewn no otherwise; of which notwithstanding the Student must have a certain Science'. For Grew as a Baconian, see below p. 136. For Wallis, see below Chapter 3, p.315 n. 2. As Newton's great predecessor, Wallis combined brilliant mathematical skills with profound belief in empirical techniques. See: J.Wallis, A Discourse of Gravity grounded on Experimental Observations Presented to the Royal Society, (London, 1675) especially pp.1-2.
2. For illuminating debate over one major influence see L.Laudan, 'The Clock Metaphor and Probabilism: The Impact of Descartes on English Methodological Thought, 1650-1665'. Ann. Sci., 22 (1966), 73-104; G.A.J.Rogers, 'Descartes and the Method of English Science'. Ann.Sci., 29 (1972), 237-255. See also M.Nicolson. 'The Early Stage of Cartesianism in England', Studies in Philology, 26 (1929), 356-74.
3. G.A.J.Rogers, op.cit., 253-254: 'Boyle distrusted a priori science in a way in which Descartes certainly did not; and his first preference would always be for empirical evidence to substantiate an hypothesis rather than a priori reasoning. This is not to deny that Boyle often recognised that sometimes it was not possible to prove an hypothesis conclusively by empirical means ...' See also, C.Webster, 'Henry Power's Experimental Philosophy' Ambix, 14 (1967), 150-178, especially 164-167.

helped to cause, and can partly explain, the evolution of a unique but not entirely homogenous view of scientific method. This melange of ideas led many post-restoration scientists to share a profound suspicion for systems, and to avow a preference for pragmatic, eclectic experimentalism.[1]

William Petty's preference in the late 1640s for more practical and less speculative scientific work is well illustrated in his response to subjects, and people, whom he knew briefly while in Paris. Thus, the letter that Cavendish sent to Petty, in April 1648,[2] reveals that he had previously written to the exiled Englishman about his anatomical discoveries and inventions. In return, Cavendish sent news of Hobbes 'who liked your letter soe well yt he desired me to lend it to him w^{ch} I did', or Gassendi, whose forthcoming book Animadversiones in decimum librum Diogenes Laerti (Lyons, 1649) was in the press, and of the Torricellian experiment. Whereas this single letter reveals that Petty initiated the correspondence with Cavendish, and then passed on the resulting information to Samuel Hartlib,[3] no other example of his link with continental science can be traced. Furthermore, when he turned his attention to optics, another Baconian interest, he concentrated on the practical utilisation of microscopes and microscopy.[4] Thus, in a letter to Samuel Hartlib of September 1648, Petty noted:

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1. For similar attitudes cf., W.E.Knowles Middleton, The Experimenters: A Study of the Accademia Del Cimento, (Baltimore and London, 1971), pp.1-7, 331-334. Dr. Middleton argues, however, that utilitarian considerations, and Baconian empiricism, had virtually no influence on the Tuscan experimentalists.
2. Letter dated 7/17 April, 1648, at Hartlib Papers, viii, 29, ff. 1r-2v.
3. Hartlib's letter to Boyle, of 9 May, 1648, quotes, verbatim, a substantial part of the Cavendish letter. Cf. Boyle, Works, (1772 ed.,) vi, 77.
4. For his continuing interest in the subject, cf. Lansdowne, Petty Papers, ii, 130-131.

'The glasses of my Microscope being it seems loose in ye window in their round Tube and fell downe and one of ye Lenses fell out, w^ch I not perceiving only tooke up the Tube and not missing ye Lens till some dayes after sought it and found it soe grated as is unfitt for any future service. In so much that now I greeve every time I remember y^t I had soe rare an usefull an Instrument whereby I have discovered m[an]y strang things both usefull and pleasant and particularly in [the making] of all [chemical] preparations'. 1

Petty's fascination with this pursuit was shared by other Baconians like Jonathan Goddard and John Wilkins.[2] Benjamin Worsley also wished to duplicate the high quality of Petty's glasses, and twice wrote to Hartlib from Amsterdam, in June 1648, asking for help and information:

'But because I heare neyther [from Fromantill] this that I have w^ch cost me 25 sh in London at a shop over against the Exchange, nor any of this sort, are so good as some that he made in France, and that MR Petty did assure me severall times he had such a one, which he valewed as I take it at 3 li sterl. MR Hobbs of Paris giving it to him. Lett ne intreat you as from yorselfe to entertayne some talke with Petty about optickes grinding of glasses, & about these microscopes, & never leave solliciting of him, till you can [obtain] a sight of his; & which having lett me begg of you, to get one of Fromantill's glasses to compare it with Pettyes, and if you find MR. Pettyes much to exceed Fromantills in goodnesse give MR Petty from your selfe what price he will have for it, if he will by no meanes sell it, shew it to Fromantill & lett him take out ye mold of the glasses, wch is easy & grind such that if it be possible wee may advance this ARt in England, & this excellent & pleasurable instrument so highly magnified by Peireskius, Gassendus, Kircherus & others & yett excelling (as use may yett be made of it) all their commendation'. 3

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1. Yale University, Osborn MSS 63/4, 'MR Petty's letter 8 Sept. 1648. The extract'.
2. Wallis reported that meetings of the '1645' group were 'held sometimes at Dr. Goddard's lodgings in Woodstreet ... on occasion of his keeping an Operator in h[is] house, for grinding Glasses for Telescopes and Microscopes ...' quoted C.J.Scriba, 'The Autobiography of John Wallis' Notes Recs. Roy. Soc., 25 (1970), 39. Wilkins first mentioned this interest in: A Discourse Concerning the Beauty of Providence, (London, 1649) p.49.
3. Copy of Worsley's letter to Hartlib, 12/22 June, 1648, Hartlib Papers, viii, 27, f.2r-2v. Another copy is at Hartlib Papers, xlii, 1, f.1r. At this stage Worsley was in Holland, working with chemists like Glauber and Kuffler, instrument makers like Fromantill, and inventors like Wheeler.

In the second letter, a few days later, Worsley expressed wonder and delight at the infinite variety of nature, calling for 'a good volume, to discover to ye world this little Atlantis, or Unknowne part of the Creation', and praising the efforts of 'Dr. Goddard & Hevelius' in optics and chemistry.[1]

These letters from Petty and Worsley illustrate the similarity of their interests, their rivalry over technical matters, and their concentration on technological aspects of a topic, which elsewhere was subjected to intense theoretical investigation. The superiority of Petty's equipment and experience is obvious from the tenor of Worsley's requests to Hartlib,[2] who once again occupied his normal role of intelligencer and confidant. Significantly, Petty's emphasis lay not on the abstract investigation of light, nor in the wonders of 'this unknown part of Creation', but on the practicalities of chemical preparation. The advantage of his superior continental equipment, apparently had an unusually effective compound microscope,[3] and of his up-to-date training with Hobbes in Paris, meant that he exhibited outstanding 'virtuosity' in this subject. While he failed to proceed with a systematic programme for the investigation of microscopic phenomena, unlike Power,[4] or Hooke a decade later, and while he produced no lasting advance

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1. Worsley to Hartlib, Amsterdam, 27 June, 1648 at Hartlib Papers, viii, 27, f.3v. Another copy is at Hartlib Papers, xlii, 1, f1.v.
2. Hartlib's Ephemerides contain many references to optical work. Cf. M.S. Ephemerides, 1648, S-T.5, reporting Haak's optical information from the Duke of Newcastle and Mersenne; ibid, H-W sheet 1, Worsley on improvement of 'crystaline glasse' for 'spectacles and burning glasses' and ibid, 1649, F-G2, for Petty's invention of a 'hand perspective' for the purblind. Hartlib also praised microscopes and telescopes in : Samuel Hartlib, his Legacie ... (London, 1652), p.61.
3. For the origins and development of the microscope at this time, cf. R.S. Clay and T.H.Court, The History of the Microscope (London, 1932), pp. 10-21; ed., C.Singer, Studies in the History and Method of Science, (Oxford, 1921), ii, idem, 'Steps Leading to the Invention of the First Optical Apparatus', 408-413.
4. For the activities of Power and Hooke cf. C.Webster: 'The Scientific Work of Henry Power. M.D. Concerned with Chemistry and Biology' (London University M.Sc. thesis, 1964), pp.92-124.

in microscopic theory or construction, Petty did evince a utilitarian commitment and level of skill which impressed Hartlib, and was envied by Worsley. His interest in the subject, and his relationship with former colleagues on the continent, therefore illuminates his attitudes during those years. One final report on his optical work clearly reinforces this interpretation of Petty's procedural, and methodological commitments:

> 'Petty shewed mee his new glasses of tubes which far exceedeth the hand perspective of Mr. Sadler, tho very good. Hee can make such as are both telescopes and microscopes, and fit them for short-sighted eyes that they shall see as well as the other best eyes. Hee hath a very singular good telescope of 4 feete long that presents in his chamber to him the gras-hopper upon the Exchange pinnacle so exactly and so neere as is wonderful. These glasses or contrivances of his are of that nature that whereas in the longer or longest of tubes the ordinary glasses cannot bee used they may in the longest with his.
>
> But hee is trying also for instruments of the parabolical and other conical figures and hopes to goe through stich with them, which is accomplished will above present wonders to our eyes as if the moone or stars lay before our feete. The charge consists not in the glasses but in making of those mechanical instruments.' 1

Petty's scientific attitudes therefore underwent considerable development after his return to England in 1646. This was partly a cause, and partly an effect of his search for financial reward, and of the desire to ingratiate himself with Hartlib to advance his social and professional standing. However, to explain why he abandoned this plan in 1650, it is necessary to give a detailed picture of his motives and activities during the previous three years.

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1. Hartlib Papers, MS. Ephemerides, 1649, A-B2.

Between 1647 and 1650, Petty clearly believed that a reputation for outstanding talent and creative energy, linked with scientific expertise and intellectual shrewdness, would secure some reward from the authorities. Once this principle was in his mind, he realised that the most effective method to advertise his growing reputation lay with Hartlib and his wide group of contacts. To this end Petty concentrated on developing a multitude of useful inventions, which would not only catch Hartlib's attention, but would also earn a living. At Hartlib's request, Petty also composed a number of expert and highly effective memoranda, commenting on various aspects of the Office of Address. On every appropriate occasion the young prodigy visited the great reformer, divulging schemes, opinions and suggestions, designed to impress their recipient. This was a lengthy process, and it took two years until the required level of support and attention was forthcoming from the older man. However, the frequency of reference to Petty in the Ephemerides of 1649 proves that his assiduous efforts led Hartlib to take a growing interest in his career.[1] Because of his personal attitude to science, his determined attempts to profit by invention, and his growing courtship of Hartlib, Petty had insufficient time, or energy, to join other London circles that were involved with natural philosophy. Apart from a late, and peripheral link with Haak, there is no indication that Petty associated, or wished to associate with the '1645' group. Evidence quoted below also shows that he only made contact with Boyle at the end of 1647. By then, the young aristocrat, with other members of the 'Invisible College', had been

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1. If the concentration of such comments are taken as a rough guide, then Petty, with twelve separate references in the Ephemerides of 1648, was successful in developing the relationship. In 1649 his name was mentioned thirty-three times.

absorbed into Hartlib's larger scheme for the Office of Address. Even the practice of medicine probably slipped behind Petty's other activities, as he relentlessly pursued the elusive rewards of invention.

It was as an unusually creative technologist that Petty laid the strongest claim to Hartlib's attention. During the debate with Henry More, Petty quoted Cornelius Drebbel as the most apposite model for the practice of science. By 1646 Drebbel was a part of English scientific folklore, with the construction of optical devices, important advances in dyeing technique, and astonishing powers of mechanical invention being ascribed to his name.[1] A natural link between Drebbel and Hartlib was fostered by the reformer's association with Drebbel's son-in-law, Johann Sibertius Kueffler. Petty's deliberate assumption of the mantle belonging to Drebbel and Plattes [2] was calculated to reinforce the image developing in the mind of his patron: that of a brilliant protege, with outstanding technical skill and the broadest range of complementary talents.

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1. For Drebbel see: W.B.Rye, England as seen by Foreigners. (London, 1865) pp.231-242; R.L.Colie, "Cornelis Drebbel and Salomon de Caus: Two Jacobean Models for Salomon's House' Huntington Library Quarterly, 17 (1954-1955), 245-260; F...Gibbs, 'The Furnaces and Thermometers of Cornelis Drebbel'. Ann. Sci., 6 (1948-1950), 32-43; L.F.Harris, 'Cornelis Drebbel : A Neglected Genius of Seventeenth Century Technology' Trans. Newcomen. Soc., 31 (1957-1959), 195-205, and sources noted therein.
2. For Plattes' role in Hartlib's schemes, 1639-1642 cf. C.Webster, 'The Authorship and Significance of "Macaria",' in ed., C.Webster, The Intellectual Revolution of the Seventeenth Century, (London, 1974), pp.369-385; A.G.Debus, 'Gabriel Plattes and his Chemical Theory of the Formation of the Earth's Crust' Ambix, 9 (1961), 162-165. Petty linked himself to Drebbel's reputation, when discoursing with Hartlib. Thus Hartlib Papers, MS. Ephemerides, 1649, A-B, notes: 'Hee approoves highly of the optical MS. of Drebbels, being the true and only way to write opticks which course himself intends to observe. Id. [Petty]'. Hartlib commented earlier: 'Hee [Petty] hath ... scanned and corrected Plats his calculations about the encrease of corne', ibid, 1643- 8-T6.

Petty first appears in the Hartlib papers as an assistant to Sir Cheney Culpeper, who was then translating a work by the important German chemist, Johann Glauber.[1] Early in 1647 Glauber's reputation rapidly increased, as new evidence arrived from Holland of significant improvements made by him in basic equipment such as furnaces and retorts. Petty's chemical knowledge and command of Dutch made him an ideal recruit for Culpeper's undertaking, although comments by the latter indicate that his young assistant failed to complete the task.[2] There is also a strong possibility that Petty was engaged by Hartlib to translate Cyprian Kinner's brief educational tract, Diatyposis which was published late in 1643 as: A Continuation of Mr. J.A. Comenius School Endeavours. Manuscript copies of this controversial pamphlet had, however, been received by Hartlib in January 1647, and it is reasonable to suppose that Petty's 'expert and industrious' translation, was undertaken during the same year.[3] While helping as a translator, Petty also aroused Hartlib's interest in his first mechanical invention, designed to make two or more simultaneous copies of a manuscript. Reports from Hartlib of this 'Double Writing' instrument led Culpeper to discuss at length its construction and possible uses.[4] His excitement at its potential exemplifies the intense interest that technological innovation attracted during this period. As an early gesture of goodwill, Hartlib promised to send one of the instruments

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1. For Glauber cf., J.R.Partington, A History of Chemistry, (reprint, London, 1969), ii, 341-361; Webster, Instauration, pp.386-8; Reference to Petty in a letter of Culpeper to Hartlib, 11 March, 1647, Hartlib Papers, xiii, f.169 v: cf. also, Dr. J.French, The Art of Distillation (London, 1651).
2. Letter Culpeper to Hartlib, xiii, f.197r, dated 20 Sept, 1647.
3. G.H.Turnbull, H.D.C., pp.432-435.
4. Hartlib Papers, viii, 31, ff.1r-3r, letter Culpeper - Hartlib, 25 June, 1647.

to Kinner.[1] In late 1647, further contributions by Petty to Hartlib's various schemes probably included lists and plans for a History of Trades,[2] and comments on the future development of the Office of Address.[3] By November 1647 Hartlib made a glowing reference to Petty in one of his exploratory letters to Boyle:

> 'And that you may have the more fuel to put into the fire, I cannot but tender to your favourable hands the other writings here adjoined, especially the design of the History of Trades. The author of them is one Petty, of twenty four years of age, not altogether a very dear Worsley, but a perfect Frenchman, and good linguist in other vulgar languages besides Latin and Greek, a most rare and exact anatomist, and excelling in all mathematical and mechanical learning; of a sweet natural disposition and moral comportment. As for solid judgement and industry altogether masculine. This is the meat or banquet, to which I desire to invite mainly all ingenious spirits and discerning palates at this time. I must know how the sauce of it (which must be at least a hundred and twenty pound per annum) will be relished; but when he hath perfected the specimen, which I have required of him, in one trade, (which also is near done) and set down all the terms and conditions upon which he desires that annual assistance, I suppose no right taste will nauseate it; ...' [4]

Hartlib's intention is plain: he was 'confident' that the chance to work with Petty in the proposed Office for Communications would attract the young nobleman. While Petty was 'not altogether a very dear Worsley', he was certainly an outstanding protege for whom Boyle might be induced to provide financial backing.

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1. G.H.Turnbull, H.D.C., p.439.
2. B.M. MSC. Volume 3, No.2,r and No.11,b, contain Petty's lists of specific tradesmen, and a complete plan of all trades, organised in alphabetical order.
3. Hartlib Papers, 1iii, 21, f.1.r, 'O. and Desiderata of O. of Addresse'. This undated, anonymous manuscript was probably by Petty, or influenced by his ideas. For a discussion of its contents see Chapter 2 below. It was most likely written in late 1647 or early 1648. A transcript is given in Appendix 2,i,below.
4. Boyle, Works, (1772 ed.,) vi, 76, letter dated 16 November, 1647.

The following year witnessed an expansion of Petty's efforts to extract financial and personal support from Hartlib and his colleagues. The Ephemerides for 1648 record that Hartlib was visited by Petty once every three or four weeks. The entries report Petty's opinion of various tradesmen, his acquaintance with Colonel Blount, a wealthy agricultural inventor, his conversations with Lord Baltimore, Governor of Virginia, and numerous details of the young man's inventions and plans for a History of Trades.[1] As a result of this growing involvement, Petty recruited Hartlib's active assistance in obtaining state support for the writing instrument. On 25 February 1648 the young inventor petitioned the House of Lords to grant him a patent 'for the sole benefit of the invention'. Attached to this petition were two affidavits outlining 'the effects and feasability' of 'double and multiple writing' and 'the profit that may redound to the Commonwealth'.[2] Listed among the names of those 'credible persons' who signed the affidavits were Lodwick, Worsley, Haak, Hartlib and Coxe. Petty's ability to gain access to parliament, and to secure the Letters Patent, probably depended on the goodwill and influence of Hartlib. Dury also tried to attract prominent backers for Petty's new invention. For example, in July 1648 he referred to the machine when writing to Louis de Geer, the wealthy Dutch capitalist.[3] Six months later, in January

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1. For Petty on tradesmen see, Hartlib Papers, M.S. Ephemerides, 1648, O-P3; for Petty and Baltimore, ibid, O-P1; for Petty and Blount, ibid, V-W6; for his inventions, ibid, S-T5; for the history of trades, ibid, [illegible]-R2 S-T5.
2. See: Seventh Report of Royal Commission on Historical Manuscripts, (London, 1879) Part 1, Report and Appendix, 11, column 2. Documents located at, MSS. House of Lords, Main Papers, February 25, 1647/8, ff. 127-129. A copy of the first affidavit is at Hartlib Papers, Lxxi, 7, f.3v. For Haak see: P.R.Barnett, Theodore Haak, op.cit.,; idem, 'Theodore Haak and the Early Years of the Royal Society', Ann. Sci..13 (1957), 205-218; for Lodwick cf. V.Salmon, The Works of Francis Lodwick: A Study of his writings in the intellectual context of the seventeenth century, (London, 1972). For Coxe see numerous references in Hartlib's Ephemerides and L.Sharp 'The Royal College of Physicians and Interregnum Politics' Med. Hist., 19 (1975), 125 and n.97.
3. Hartlib Papers, iv, 1, f.21r. letter Dury to Hartlib, 14 July, 1648, noting his correspondence with de Geer. For de Geer see V.Barbour: Capitalism in Amsterdam in the Seventeenth Century, (Baltimore, 1950) pp.36-40, and passim.

1649, Dury was again recruiting support, this time in London:

> 'Deare freind ... I send this before to let you know, yt the Prince Elector is desirous to speake with MR Pettie, & yt I would intreat him to name a day in this weeke following & the time of the day wherein he will bee at best leisure to go to him; & let the Prince know it by a Note from you; by my intreatie because of my absence from towne who could not notifie it myselfe to him. I desire MR Pettie to name such a day yt the Prince may have notice thereof two dayes before, yt there may bee no cause [for] disappointment on either side. The Prince will bee desirous to see some proofe of the thing before he enter in termes of agreement ...' 1

This was therefore the period when Petty's campaign to gain recognition for the invention reached its first crescendo. In April 1648 he published a broadsheet and ten-page pamphlet outlining the merits of 'Double Writing' and giving details of the patent.[2] He also provided Hartlib with drafts of the pamphlet and a number of different short essays, which described its practical value and the conditions required for its sale, or for disbursal of a share in the expected profits.[3]

Two months later Petty sent a curious letter to Robert Boyle, which accompanied his gift of one of the double-writing instruments.

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1. Hartlib papers, iv, 1, f.22r. Letter Dury - Hartlib, 23 January, 1649. For a similar situation see Wren's letter to the Prince Elector, c.1646, in C. and J.Wren, Parentalia ... (London, 1750), p.183.
2. Broadsheet headed Double Writing, the Brit. Mus. copy (K.669, f.12/2) dated '6 Aprill, 1648', gives Petty's address as 'next to the White Bowre in Holbborn'. cf. Keynes, Bibliography, 3. [W.Petty], A Declaration Concerning the newly invented Art of Double Writing, (London, 1648) dated, in Brit. Mus. copy (E.437.(23)), 'Aprill 29, 1648', cf. Keynes, Bibliography, 2. A copy of this pamphlet is at Hartlib Papers, lxxi, 7, ff.
3. Hartlib Papers, lxxi, 7, f.2r, 'The nature and uses of ye double writing instrument'; ibid, f3, 'There is invented ...', single sheet describing the instrument; ibid, ff.5 + 6. two copies, 'All the waves of raising profitt from the Invention ...'

In the letter Petty explained that he had dedicated this 'useful and new invention' to Boyle, because he was the 'Maecenas of such things'. Petty said that by sending the machine he did not expect to impress the young nobleman, since its construction was so simple; neither was it a valuable gift, since other subscribers could buy a share in the profits for a mere five shillings; nor, given his social position, could Boyle be expected to advertise its use among tradesmen, though Petty did add the request that he 'promise upon ... [his] ... honour a deep and absolute silence to all enquiries after it'. Instead, Petty argued:

> 'It is only because I hope hereby to oblige your noble and ingenuous spirit so much the faster to continue your love and assistance to inventions, and other real fruits of learning and arts. For if the world imbrace the use of this invention, you may, by God's ordinary providence, live to see a thing, whereof you have the very maidenhead and patronage, to be of daily and almost hourly use to most men in most countries of the whole earth, and that to perpetuity; and consequently your own name made equally universal and known, although bright and glorious by your own deserving actions'. 1

The tone of this disengenuous, even fawning letter probably did little to endear Petty to Boyle, who remained critical of attempts to benefit from exploitation of secret knowledge.[2] In fact, Petty kept the main reason for writing to Boyle until the final paragraph of the letter:

> 'There is yet another, why I have entrusted you with it, which is, because I, having concredited unto you all my treasure of this nature, may hope for some of your experiments to be en-

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1. Boyle, Works, (1772 ed.,) vi, 136-137. Letter dated 21 June, 1648.
2. For Boyle's rejection of secrecy over inventions and therapeutic medicines see: R.E.W.Maddison, 'The Earliest Published Writings of Robert Boyle' Ann. Sci., 17 (1961), 165-173.

> trusted unto me. For my study and ends being enquiries into nature, and useful arts, and finding how ill my abilities to make experiments answer my inclinations thereto, I knew no readier way to become fat in that kind of knowledge, than by being fed with the crumbs that fall from your table ...' 1

Petty's attempt to gain tacit support for the invention from Boyle, coupled with his efforts to insinuate himself into Boyle's confidence, probably had a negative effect and may explain why the two never became close friends, despite working together between 1652 and 1654.

Petty's entrepreneurial efforts were carried one stage further in September 1648, when he concluded an agreement with 'John Holland of Deptford, Gent'. Holland agreed to give the young technologist £220 in return for a half share of the profit from the invention.[2] Furthermore, he guaranteed to pay all charges '[incurred] in making Vessells or buying Materialls for Experimenting', and both men were given carefully defined rights of compensation for default by either party. This agreement clarifies the progress made by Petty in trying to gain financial support for his work. The exclusive nature of the contract establishes that his attempt to derive an adequate income from the patent, and from public subscription, had failed by the autumn of that year. Consequently, he was forced to accept the limited, but secure offer made by Holland, at the cost of fifty per cent of the financial return. Such agreements were not uncommon, and Hartlib's papers contain a number of similar documents in which Boyle, Culpeper, Dymock, Kueffler, Tonge and Hartlib appear as interested parties.[3] What is significant is the size

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1. Boyle, Works, (1772 ed.,) vi, 137.
2. 'Articles of Agreement' between Petty and Holland, 30 September, 1648, at B.H. MSS. Volume 8, Number 43.
3. See Hartlib Papers, lxii, 48, f.1r, bond for improvement of corn-planting machine, with signatures of Culpeper (for £20) and Boyle (£10); 'Articles tripartite ... betwixt ... Kueffler ... Hartlib ... Tonge' 20 June, 1656 at Hartlib Papers, xxvi, 49, ff. 1 + 2; and Dymock's agreement with Hartlib, 17 April, 1650, at Hartlib Papers, viii, 45, f.1r.

of the sums mentioned in the Petty-Holland contract, and the fact that this agreement, like many others, failed to produce the desired result.

To win Hartlib's support Petty contributed several essays and memoranda to the debate over social reconstruction. In addition to a draft of 'A Memoriall for [the] advancement of Universall Learning',[1] Petty probably wrote the brief 'Q[uestion] and Desiderata of [the] O[ffice] of Addresse'. These were both intended as policy statements which would be incorporated in the wider published programme of educational reform. Petty's major contribution to this programme was The Advice of W.P. to Mr. Samuel Hartlib for the Advancement of some particular Parts of Learning.[2] This short tract, which will be analysed in greater detail below, was Petty's first important published work. It not only gave a detailed picture of his specific recommendations for education, but also of his more fundamental principles. The treatise is prefaced by an advertisement for the 'Art of Double-Writing'. This invention, Petty argued, might provide sufficient money to 'at least set the aforementioned Designs on foot'. He therefore:

> 'reassumed my Meditations ... desiring you and your Ingenious Freinds to remeditate upon them and correct them, but withall to think of the best course, how to improve my Invention to such advantage, as may if possible, make us capable of enjoying more then bare Ideas of that Happinesse, which the atchievements of our designs promiseth'. 3

With this reminder to Hartlib of his major requirement, Petty then stressed the quid pro quo aspect of the situation:

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1. See description and text of one of the copies of this manuscript, in Webster, Instauration, pp.551-553. Variants of this text are at Hartlib Papers, xlvii, 1, ff.7-8, 9-10 and xlvii, 4, ff. 2v-4r. For Petty's contribution to these educational deliberations see Chapter 2 below.
2. Cf., Keynes, Bibliography, 1. (Petty's work henceforward referred to as: Advice).
3. Petty, Advice, Big Adv.

> 'Having written it (as Your self must beare me witness) at your own Importunity in the midst of my cares and indeavours to perfect mine Invention, and which is work in the midst of my hard and perhaps unprofitable labour, to prevent the ingratitude and backwardnesse of men to reward [me] ...' 1

Even when he was contributing to the supposedly selfless work of reform, Petty's personal needs were never far from his mind. Although Hartlib was aware of this flaw in his character, it did not stop him from expressing a growing interest in Petty's career, nor from utilising his contributions to the general campaign for reform. Consequently, he distributed copies of Advice and received a number of comments, or written appraisals, in return.[2] 1648 was therefore the year when Petty established a close working relationship with this influential and selfless man, whose only concern was for the improvement of the human condition.

The following year saw this relationship reach its apogee. The Ephemerides contain numerous lengthy reports on the amazing range of Petty's activities and thoughts. His inventions for brewing, agriculture, dialling, distillation, draining, sugar production, dyeing, optical investigations, and printing, receive copious attention. At the beginning of the year, Hartlib noted:

> 'Some tradesmen have applied themselves to Petty with certain offers which if he can accomplish, they promise him all manner of provision both for himself and his designes. Now hee conceives that the things they demand are possible to him. But what they are hee will not tell'. 3

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1. Ibid.
2. Letter Symner to Hartlib, 24 October, 1648, Brit. Mus. Sloane MSS. 427, f.35, comments on the Advice. A larger commentary: 'A Remonstrance of the feasability of the Designes described by W.P. in his Advices to MR. Samuel Hartlib ...' is at Hartlib Papers, liii, 36, ff.1-2v.
3. Hartlib Papers, MS. Ephemerides, 1649, B-C5.

This technical expertise suggested to him an ideal role for Petty in the broader reform programme:

> 'The designe of worke-houses seemes to bee blasted by the reason given by the Moderate Intelligencer No. 207 and the remedie proposed better liked of, which is to invent a hundred new imploiments etc or enterprises in which the poore should be invited or ordered to worke. Petty were very fit to give a list of such kind of emploiments and inventions which might also serve for the idle souldjery kept up in the kingdom. Petty' 1

Hartlib discussed this idea with the young technologist who responded enthusiastically, since directing a state programme for employment would be socially beneficial and would enhance his own prestige and wealth. To Hartlib's suggestion, Petty replied that:

> 'if hee bee called by the Common Councel hee then will undertake to invent a number of brave enterprises upon which the poore may bee imploied'. 2

To reinforce Hartlib's belief in his sincerity, and also as genuine philosophical statements, Petty imparted to him certain fundamental ideas. It is into this niche that his letter to Henry More, and his comments on 'real experimental learning', must be fitted. Petty continuously underlined this bias towards Baconian experimentalism, and its concomitant moral attitudes, when discoursing with his patron:

> 'More's Utopia a most excellent booke, one of the best English wits counted by Petty in all State affaires, as Verulam the other Chancellor was one of the chiefest men for other reall learning'. 3

and,

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1. Ibid.
2. Ibid.
3. Ibid., D-E6. Compare, Sir T.More, The Commonwealth of Utopia (London, 1639), ii, 107-305, with Petty's various schemes for improvement and socio-medical reform.

> 'What Verulam's Natural History is in Philosophy the same parallel for Ethicks or Moral Histories is most exactly couched in Ben Johnson's works, to the readers admiration expressing the characters of all humours and behaviours whatsoever. Petty'. 1

He also outlined several projects which related both to Hartlib's educational plans, and to the general advancement of learning:

> 'Petty proposed also a designe how to runne over the whole experimental philosophy by way of cursus without all books upon the things themselves, which might soone bee accomplished and set on foot without charge. As of physical, anatomical, botanical, optical, astronomical, musical, mechanical etc. reall lectures, according to the seasons of the Year'. 2

Such references establish the adherence, or at least attraction, felt by Puritan reformers towards Baconianism. Although Petty cannot be described as a 'Puritan', in the religious sense of the word, his view with regard to social, economic and educational problems appealed to colleagues who possessed this fundamentally religious outlook. Therefore (despite different motives) when Petty advocated sweeping social reform and promised to engineer this reorganisation himself, Hartlib was willing to give his full support. This is best exemplified by the space which Hartlib devoted in the Ephemerides to Petty's schemes. The following report typifies the nature and content of these grandiose plans, illustrating the role that Petty wished to play in Hartlib's programme:

> 'Petty hath compleated a universall designe to further the good of the commonwealth as much as Dr. Chamb[erlen?] undertakes in his Advocate for the Poore. 3 But it hath none of all

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1. Hartlib Papers, MS. Ephemerides, 1649, F-G7.
2. Ibid., F-G1.
3. For Peter Chamberlen, The poore man's advocate, (London, 1649) cf. Bibliography of British History, Stuart Period, 1603-1714, (Oxford, 1970) no.2523, with other literature concerning employment of the poor, and economic improvement, noted therein.

> those inconveniences which accompanie his contrivances. By this all taxes will bee taken of from the people etc. all the poore provided and set a worke, the History of Trade instantly set upon etc. Hee hath imparted his conceptions to some able heads of his secret acquaintance who can object nothing against the feasability of it. All hee intends to compromise in one sheete and then to receive face to face whatsoever can bee alledged against it. Or to impart it more politikly to some of the Council of State or Parliament's leading grandees, if hee can get so far into any of them that hee may make them his conduit-pipe and himself the fountaine in secret out of which they may bee supplied from time to time, so that they may have the sole credit and glory of the designe in publick from time to time. For otherwise the best designes will never bee favoured effectually by states-men who laugh and slight rather then promote when anything of consequence is proposed nakedly to the publick view'. 1

Petty's cynicism about aid from prominent figures suggests bitter experience. This situation, and the competition for support among projectors and inventors, is outlined in several letters exchanged by Worsley and Petty during the first half of 1649.

Benjamin Worsley's first epistle, of January 13/25, was despatched from Holland.[2] He had gone there the previous year at Culpeper's request to investigate Dutch technology and industrial practice.[3] Involvement with Kalthof and Wheeler introduced Worsley to some of the most advanced industrial research. In particular, Kalthof was developing a new generation of pumps and drainage machines, which were in direct competition with Petty's own designs. Worsley, and occasionally Hartlib, acted as intermediaries for the two inventors. On this

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1. Hartlib Papers, MS. Ephemerides, 1649, C-D8 to D-E1.
2. Letter Worsley - Petty, at Hartlib Papers, viii, 50, ff. 1-2v.
3. Letter Culpeper - Hartlib, discussing the merits of Glauber's chemical texts, Hartlib Papers, xiii, 197, f.1r, dated 20 September, 1647 '(yf Mr Worsley will ... become mye ffactor, and to goe over to Glauberus, and to purchase his ingenuities of him, I shall be willing to become a merchant adventurer in the business ...'

occasion Worsley praised Petty's offer to give Kalthof information, saying 'you could not seriously have surprised mee in any thing more, or easily have given mee greater cause, passionately to love you ...' Petty's 'willingness' to 'lay a foundation of union and friendship' with Kalthof, (using Petty's own words) had 'much honoured' the English inventor. After discussing Kalthof's views on natural philosophy, Worsley transmitted various detailed questions, composed by Kalthof, about Petty's experimental plans. He concluded with Kalthof's request that, since they were different, perhaps Petty might refrain from copying, or questioning, his competitor's designs?[1]

Petty's reply was shorter, but no less civil:

> '... as for some of the q[estions] you make cond[erning] my notion I have longe since debated them and conclude that some of them cannot bee solved without actual experience, for the rest i have very effectual remidies. I am glad to heare MR Kalthof's notion is tote Caso different from mine supposing thereupon that there is more Art in the World then i thought there was, and wish his profits may bee according to his deserts. For my part I shall bee willing to promote it without the least respect to myself I am also glad that hee communicated his hypothesis and grounds unto you, and since you know it, and altho[ugh] i ca'not wrong him by knowing it myself by your communication nonetheless my patience hath beene so exercised of late that i can bee contented to stay till the thing bee publique ...' 2

The disappointment Petty felt over his failure to gain recognition showed through in this letter. However, despite this air of veiled cynicism, the final remarks contained fulsome praise for Worsley's advanced scientific knowledge, and demanded to know 'what extraordinary experiments' his correspondent had seen in Holland.

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1. Letter Worsley - Petty, 18/25 January, 1649, Hartlib Papers, viii, 50, ff.1-2v.
2. Letter Petty - Worsley, 23 January, 1649, Osborn MSS.63/4. (Yale University), f.1r.

The recurrent theme of disappointment nevertheless continued in Petty's next letter. There, he informed his colleague about problems the experimental boling engine would encounter if used in the 'sugar-mills' of Barbados:

> 'I am so farr from being courted by the Men of this world, or from desiring or deserving it, for my creditt is so small with them, that they scarse believe my performances to be reall, although they see them; from whence you may gather how much they laugh att me, when I doe but barely propound them, or how much they would scorne or deride me for any failing in them, out of all which you may conclude, that I neither have as yet, nor will make proclamation of any of my Inventions ... Sir, I have & doe dayly find so many and so greate difficulties in extracting proffitt of any Invention whatsoever, that I could not bee so traiterous to any friend to advise him to buy out his Estate in setting up theise Engines in a farr Countrey uppon bare directions given here, when it is so hard to find all Instruments to that purpose, and yet more hard to gett the rewards when the worke is safely accomplished'. 1

This disillusion did not prevent Petty from a further attempt to profit by his inventions. Two days after he wrote the letter he induced senior members of the Brewers' Company to sign an affidavit substantiating his claims for the boiling engine.[2] He also composed advertisements for various 'dialling' (surveying) instruments.[3]

At the same time Hartlib and Worsley also tried to find support for Petty. In their letters of May and June 1649, they made frequent

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1. Ibid., Letter Petty - (?) Worsley, 14 March, 1649, ff. 1r + v.
2. Affidavit in Petty's handwriting, dated 16 March, 1648, at Hartlib Papers, viii, 11, f.1r. This is similar to the document obtained (1652) by Bushell from the College of Physicians, about mining and minerals, Cf., T.Bushell, An Extract by Bushell ... of his ... Abridgement (London, 1660) p.50. For Bushell see: J.W.Gough, The Superlative Prodigall : A Life of Thomas Bushell, (Bristol, 1932).
3. Manuscript advertisement, Hartlib Papers, viii, 11, f.2r, in Petty's hand, headed 'Dialling'. Cf. Appendix 1, i, below.

reference to the idea (suggested by Petty) of combining his talents with those of the other leading inventor:

> 'If Kalthof and Petty might be joined together they might doe wonders, as well for their owne benefits privately as otherwise. I meane for the Privilege of it in France and other Countries. For Kalthof hath great relations and advantages, not only from his parts, but from his friends and interest in the Court and in many eminent Persons in this land'. 1

The obvious location for the partnership was the Marquis of Worcester's vacant engineering laboratory in Vauxhall, which was then in parliamentary hands. Hartlib hoped to persuade the authorities to retain the building, with all its resources, as a centre for invention. Envisaged as a technological research institute, constituting one part of the ever-changing Office of Address, it was to employ Petty and Kalthof as two resident experts. When this scheme failed to materialise, Hartlib put forward another one. In a letter to Boyle of July 1649 he said:

> 'As for Vauxhall, there is a proviso put into the act, that it shall not be sold. My endeavours are now, how Mr Petty may be set apart or encouraged for the advancement of experimental and mechanical knowledge in Gresham College at London, of which you shall have a true account also, ... ' 2

This letter, and the location of the memorandum 'For setting Fauxhall apart for Publick Uses',[3] indicates that Boyle was kept closely informed about these schemes. In Hartlib's view, Gresham College was

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1. Letter Worsley to (?) Boyle or Hartlib, Royal Society M.S., Boyle Letters, vii, Letter 1(i). For Worsley's other letters at this time see, ibid, letter 2, dated 1/4 June, 1649; Hartlib Papers, xxvi, 33, ff.1-3, 22 June, and ibid, ff.8-9v, undated, but c.June, 1649. Petty is mentioned in all these letters.
2. Boyle, Works (1772 ed.,) vi, 78, letter dated 24 July.
3. 'A Memorandum for settling Faux-hall apart for Publick Uses' at Royal Society MS., Boyle Letters, vii, attached to Letters 1 and 2.

an appropriate location since Petty had already put forward specific plans for its reorganisation. These demanded its transformation into an advanced College for technological instruction and research.[1]

In August, Petty made a last attempt to gain governmental support for his work as an inventor, by petitioning the Council of State. With the help of Henry Morris he presented a lengthy 'Remonstrance' which, in return for £1,500, promised to divulge the secret of the 'Double-Writing' instrument.[2] Like the rest of Petty's schemes this petition came to nothing. In October 1649 Petty received another body-blow when his brother died. Anthony had accompanied him since the early days in Holland, acting as a most competent assistant in chemistry, mechanics and anatomy.[3] His loss crippled Petty's technical operations, making eventual success in this area more unlikely.

The end of the year faced Petty with a bleak situation. Although his time in London led to integration with Hartlib and his influential circle of friends, it failed to provide the necessary advancement. While he derived important ideas on government, economics and technology from this experience, immediate rewards still eluded him. His claim to the mantle of Drebbel and Platter had achieved nothing. Therefore, at the start of the new decade he changed course, and followed more traditional routes to financial[4] and professional success.

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1. For this scheme see Webster, Instauration, pp.222-3. Petty wrote a memorandum on Gresham College in late 1648 or in 1649. It is at Hartlib Papers, xlvii, 18, ff.1-2 and discussed below in Chapter 2.
2. Appeal dated 22 August, 1649. Cf. Cal. Stat. Pap. Dom. 1649-1650, ed., M.A.E.Green (London, 1875) ii, 233. Manuscripts at Public Record Office, S.P. 18, Volume 2, ff.156-159.
3. Fitzmaurice, Life, Petty's Will, p.323, notes date of Anthony's burial as 18 October, 1649. Hartlib provides evidence of these skills in the Ephemerides for 1649. Cf., B-C2, F-G6, and G-H5, which notes: 'Petty ... told mee again that hee had brought his printery into practice, but by the death of Anthony ... it was like to bee laid by'.
4. In his Will, Fitzmaurice, Life, p.319, Petty reveals that from 1645 to 1650, he failed to increase his capital assets, beginning and ending the period with £70.

(c) Oxford : Science and Medicine, 1650-1652:

William Petty outlined the new direction his career would take, when writing to his cousin in March 1650. Couched in a friendly and confident manner, the note offered John a base in London (to practise his trade of weaving) and a chance to act as his relative's medical assistant. Petty also asked for John's help in other areas:

> 'And now Anthony, who assisted mee in these things, beeing dead, and lastly because I may now againe undertake some of these things, as chymistry and anatomy, whereby I let him gett somewhat for himselfe, and moreover hearing you much desire to bee about London, I have thought fitt to know whether your desires continue the same ... If I undertake anything in Chymistry or Anatomy, whereupon I shall need your assistance, if your assisting mee therein will bee more profit or pleasure to you than your other worke, you shall have the employment: otherwise not. If any invencion which I set you aboute, take effect, you shall have a share in the benefitt arising from it ...' 1

Petty confirmed this new emphasis by stating that he intended 'God willing, so soone as possibly I can, to take the degree of Dr. of Physicke'.

The practice of medicine, like the practice of law, has always provided a classic route to professional advancement. This traditional path became increasingly attractive during the Civil War period as military, governmental, and civilian demand for medical personnel expanded enormously. The medical profession was also one of the best educated and most highly skilled of professional groups, and provided a natural source of recruits for the burgeoning civil administration.

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1. Letter dated 7 March, 1650 at B.M. MSS. 6, ii, no.4. Printed in Fitzmaurice, Life, pp.13-15.

A significant number of outstanding medics such as Whistler, Goddard, Worsley and Petty, exploited these opportunities to make rapid social and professional progress.[1]

It is therefore reasonable to assume that from late 1649 Petty energetically developed his medical career. Medical notes dating from early 1650 indicate that he swiftly built up an important practice.[2] His patients were generally drawn from the middle strata of society, but a significant number were dependants of high-ranking military and civilian figures. Some of these were instrumental in furthering the young doctor's progress. Thus, the first reference to Petty's relationship with John Graunt can probably be linked to his extensive treatment of a 'Mrs Grant' and her children.[3] The medical diary also refers to patients such as 'Sr Henry Roes Sgt Major',[4] 'Sr H.Roes Mayd',[5] 'Sr Henry Vanes mayd'[6] and to 'Mr Hodges child', whom Dr George Bates, one of Cromwell's senior physicians, handed to Petty '[by] his appointment'.[7] A significant part of his practice centred on the city of London, particularly in Lothbury and the area surrounding Birchin Lane. This, together with the link through the Graunt family, was of direct relevance to Petty's subsequent campaign for academic preferment.

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1. Cf. L.Sharp, 'The College of Physicians ...' op.cit., 110-113; Webster, Instauration, p.84. For Whistler see: J.J.Keevil, Medicine and the Navy, 1200-1900, (Edinburgh and London, 1958), ii, 13-20.
2. Notes at B.M. MSS. Volume 3, Item 6.
3. Ibid, pp.13, 15, 27, 31. For Graunt see: D.V.Glass, 'John Graunt and his Natural and Political Observations' Notes Recs. Roy. Soc., 20 (1965), 63-100.
4. B.M. MSS. Volume 3, Item 6, p.13.
5. Ibid., p.14.
6. Ibid., p.17.
7. Ibid., p.3.

If medicine offered a rewarding path to professional success in 1649, then an equally exciting prospect was beginning to develop at Oxford. By 1650 the parliamentary Visitors to the University had made large-scale ejections of recalcitrant academics.[1] In March of that year, John Lydall, a Fellow of Trinity College, wrote to John Aubrey that this process was expected to continue:

> 'I do not wonder, that you should heare of another purging of the university which although it bee not yet done, will in all probability bee shortly, so that ye report you heare may bee received as a good prophecy although not as a true history ...' 2

It is therefore not surprising that Petty thought the combination of medical practice, and/an academic post, offered outstanding opportunities. Despite his caustic comments to More c. February, 1649, paragraph 7. about the vapid quality of university intellects,[3] and his openly radical views on medical education,[4] Petty joined the stampede for preferment at Oxford.

On 11 March 1650 Petty was awarded his D.M. at Oxford 'by virtue of a dispensation from the delegates of the university, who had received sufficient testimony of his rare qualities and gifts from Lieut. Col. Kelsey the deputy governor of Oxford garrison'.[5]

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1. Cf. Webster, Instauration, pp. 131-3; The Register of the Visitors of the University of Oxford, 1647-1653, ed., M.Burrows (Camden Soc. Pub., 1881) Introduction and passim. R.G.Frank, 'Oxford and the Harveian Tradition...' op.cit., passim.
2. Bodleian Library, MS. Aubrey 12, f.306r. Letter dated 11 March. See also: R.G.Frank, 'John Aubrey, F.R.S., John Lydall, and Science at Commonwealth Oxford' Notes Recs. Roy. Soc., 27 (1973), 193-217.
3. Cf. above, Letter to More c. February, 1649, paragraph 7.
4. Cf. L.G.Sharp 'The College of Physicians ...' op.cit., 122 and Chapter 2 below.
5. A.Wood, Fasti Oxonienses, ed., Bliss (London, 1820), ii, 156. Petty's admission recorded at Bodleian Library, MSS. Oxford University Archives, Q.b.18, 'Registratum Congregationis: 1648-1659', f.9v. John Petty was admitted as B.A. 23 March, 1650, ibid, f.10r. For Kelsey see D.N.B.

Kelsey, 'a godly button-maker' from Birchin Lane, brother-in-law to John Graunt (also from Birchin Lane), and devoted supporter of Cromwell, enabled Petty to take the first essential step in academics. The day after this success, Thomas Gilson, a strong supporter of educational reform at Corpus Christi College, wrote to Hartlib:

> 'Sr, some dayes since I happily fell acquainted with MR Petty whom I have found a very ingenious e much deservinge gentleman, I could hartily wish him preferred in O[u]r University; only I would willingly be informed how he stands affected to ye Parliament e what preferrment he would accept'. 1

Petty's abilities were soon given appropriate recognition. In June 1650 he was elected a candidate of the College of Physicians, and in August he wrote to Dury that 'I have ye Grant of ye Anatomy Lecture at Oxford, and as soone as I can goe downe, may have the same confirmed ...'[2] He was not, however, content to take on Professor Clayton's duties for the limited stipend of £15 per annum. Instead, he asked for support from Dury and Hartlib in his struggle to gain one of the academic posts which would be vacated after the forthcoming 'engagement' in Oxford. Petty argued that he deserved a position 'For a further Reason Viz the bettering of my poore salary to pleade on my behalfe'. If Hartlib and Dury would try to influence the London Committee in his favour, Petty would also obtain supporting letters 'from the University desiring the same thing ...' Evidently, Petty's supplication was effective: the influence of colleagues from London paved the way for his election to a Fellowship at Brasenose College in

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1. Letter 12 March, 1650, at Hartlib Papers, X, 1, 13.r.
2. L.Sharp, 'The College of Physicians', op.cit., 121. Petty's letter to Dury dated 26 August, 1650 at Yale University, Osborn MSS. 63/4.

September 1650.[1]

This meteoric progress did not end with Petty's election to Brasenose. He was created Professor of Public Anatomy at the beginning of January 1651[2] and, at about the same time, was elected Vice-Principal of his college.[3] A month later, Petty again called on the support of his London friends (including Lady Ranelagh) to help him obtain the post of Music Professor at Gresham College.[4] This event duly took place at the beginning of February,[5] though, as Aubrey later reported, the deciding influence was exercised on Petty's behalf by John Graunt.[6] Within the space of a single year, Petty's fortunes had therefore undergone a remarkable change. By the spring of 1651, his academic and medical rank were such that all his plans and projects were dignified by a superior worldly status. He had obtained preferment by capitalising on contacts assiduously developed during the bleak years of the previous decade. However, this exploitation, and the decision to go to Oxford, showed that he no longer be-

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1. Brasenose College MS. Vice-Principal's Register, 1594-1696, f.75r, report of 'Committee for the Regulating of the Universities' dated 12 September, 1650.
2. Nomination of Petty by Clayton to Toulins lectureship (copy), dated 31 December, 1650 at B.M. MSS. Volume 8, no.44; Petty's petition to Vice-Chancellor for post of Professor of Public Anatomy (copy) at Ibid, no.46; document granting the appointment on behalf of the Vice-Chancellor and Proctors, dated 1 January, 1651, at Ibid, no.45.
3. Brasenose College MS. Vice-Principal's Register, 1594-1696, f.76v.
4. Cf. undated letter, signed 'Lothbury, Tuesday night' referring to the 'Comm[i]ttee day with my Lord Mayor ...' at Yale University, Osborn MSS 63/4.
5. Document noting Petty's election at Gresham, dated 7 February, 1651, signed by the Lord Mayor and the committee, at B.M. MSS, 37 Box H 'Royal Society', folder 2, (ii) b. See also, J.Ward, The Lives of the Professors of Gresham College, (London, 1740), pp.217-227.
6. Keynes, Bibliography, p.87.

longed to Hartlib's 'palse - spirited'[1] band of reformers, the more so when he deliberately suppressed his radical views on education and medicine to gain advancement. From 1650 onwards Hartlib's influence on Petty waned as his position and ideas developed their own momentum.[2] The latent antithesis between the selfless reformer, motivated by deeply-held religious belief, and the ambitious, secular exponent of natural philosophy and technology, slowly, but inexorably emerged. In 1652 the suspicion voiced by William Brereton about the 'Doctor's' motives (a frequent term of reference for Petty) established the keynote for his later dealings with the Hartlib circle:

> 'though (I doubt not) the Dr will tell you, here is no encouragement for learned men, or else that all places are filled. But the truth is, he loves not to take much pains for others; and therefore thinks, he hath sufficiently discharged the part of a friend, in inquiring of such men as being gotten into good places themselves will endeavour to keep out all others, though never so much their friends ... MR Fleetwood told me he would write to you today; and so did ye Dr of whom I have said enough, though not too much ...' [3]

Henceforward, Petty's relationship with figures such as Hartlib, Worsley, Pell, and even Boyle, was to become more problematic.

If Petty's brief stay at Oxford was of primary importance because it conferred prestige, it also helped him make some highly significant personal contacts. Inevitably, given his talents and inter-

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1. Phrase used by Gilson in a letter to Hartlib dated 1 January, 1650 at Hartlib Papers, x, 1, f1r.
2. The number of references in Hartlib's Ephemerides declined accordingly, from 12 in 1650, to 6 in 1651 and none in 1653.
3. Brit. Mus. Sloane MSS. 4278, f.104 r, letter Brereton - Pell dated 5 March, 1651. For a strong condemnation of the consistent pursuit of self interest, under the guise of 'procuring a Publique Good', which Dury described as 'carnall Hypocrisie', cf. J.Dury, A Motion Tending to the Publick Good (1642) in Webster, Advancement, p.[illegible], paragraph 5. See also [Samuel Hartlib] A Further Discoverie of the Office of Publick Addresse, (London, 1643), p.2.

ests, he became involved with the large, informal and enthusiastic circle of natural philosophers who congregated in the city after the civil war.[1] As Wallis reported many years later:

> 'About the year 1648, 1649, some of our company being removed to Oxford (first Dr. Wilkins, then I, and soon after Dr. Goddard) our company divided. Those in London continued to meet there as before (and we with them, when we had occasion to be there;) and those of us at Oxford; with Dr. Ward ... Dr. Ralph Bathurst ... Dr. Petty ... Dr. Willis ... and divers others, continued such meetings in Oxford; and brought those Studies into fashion there; meeting first at Dr. Pettie's Lodgings, (in an Apothecaries house) because of the convenience of inspecting Drugs, and the like, as there was occasion; And after his remove to Ireland (tho' not so constantly) at the Lodgings of Dr. Wilkins, then Warden of Wadham Coll.' [2]

Although Wallis' memory can be faulted over certain details in this account,[3] it is still an important source of information on the famous Oxford 'Club'. In fact, Petty's comments indicate that more than one informal grouping existed between 1650 and 1652. For example, he noted in his Will thirty-five years later that 'in less than four years more I obtained my degree of Doctor of Phisick in Oxford, and forthwith thereupon to be admitted into the College of Phisitians, London, and into several clubbs of the virtuous ...'[4] In 1651 Hartlib reported in the Ephemerides that:

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1. Cf. Webster, Instauration, pp.144-178; Frank, 'Oxford and The Marvelian Tradition' op.cit., passim; M.Purver, The Royal Society: Concept and Creation, (London, 1967) especially 100-127; B.J.Shapiro, John Wilkins, 1614-1672, An Intellectual Biography, (Los Angeles, 1969) especially, pp.113-117. On scientific subjects Shapiro's biography is inadequate.
2. C.J.Scriba, 'The Autobiography of John Wallis' Notes Recs. Roy. Soc., 25 (1970), 40.
3. Purver, The Royal Society, op.cit., pp.177-178.
4. Fitzmaurice, Life, p.319.

> 'Dr Petty['s] Club amongst other experiments have made one of snow candles, but they are more for curiosity than any real use ... The Clubmen [at Oxford] have cantonized or are cantonizing their whole Academia to taste me [Petty] to several imploiments ...' 1

Petty's (untraced) letter to Hartlib, therefore differentiated between the larger group of 'Club-men' and his own smaller 'Club'. The former group was probably the one which Langbaine hoped to organise, under his well-known set of rules, in October 1651.[2] Its members (at least twenty) also agreed to help him catalogue the Bodleian Library. Langbaine's list of the individuals conscripted for this task included Wilkins, Wallis, Robinson, Bathurst, Ward, Willis, Lydall and Robert Wood, but omitted Petty.[3] This would suggest that Petty's smaller group was separated from the main body of natural philosophers, owing to its specialisation in bio-medical subjects such as chemistry, anatomy and surgery. However, this did not exclude Petty, or indeed anyone else, from participating in the meetings of the larger 'Club' or in those of any other private circle.

This tentative picture of a plethora of groups, coalescing and disbanding as new interests developed and as changes in personnel took place, seems far more realistic than one which pre-supposes a single, dominant Club. It matches the situation in London both before, and after, the Civil War, when the range of such circles included Gresham College, the '1645' group, Boyle's 'Invisible College', Hartlib's 'Office of Address', the College of Physicians, and informal associ-

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1. Hartlib Papers MS. Ephemerides 1651, A-B2.
2. Bodleian Library, MS. Ashmole 1810. Cf. Purver, op.cit., p.111.
3. Langbaine's Lists at Bodleian Library, MS. Wood. Donat 1, pp.1-3.

ations between men like Charleton, Evelyn and Pierrepoint.[1] Indeed the University, with its collegiate divisions, tended to encourage the evolution of small, private groups which left few traces. These have often escaped the historian's attention.[2] On the other hand associations could, and did, develop at Oxford which transcended these collegiate demarcations. In Petty's case he belonged to one such coterie, which included a preponderance of doctors like John Baber, John Maplett, Thomas Willis and Richard Lower.[3] He also joined the activities of the larger 'Club' which, since then, has always been associated with figures like Wallis, Wilkins, Wren,[4] and Ward. It was due to such free association in Oxford that Petty became involved with many of the men who helped found the Royal Society after the

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1. On Gresham see: C.Hill, Intellectual Origins, op.cit., pp.34-67, and passim; F.R.Johnson, 'Gresham College: Precursor of the Royal Society', J.Hist. Ideas, 1 (1940), 413-438; Webster, Instauration, passim; see also: C.Webster, 'The College of Physicians: "Solomon's House" in Commonwealth England' Bull. Hist. Med., 41 (1967), 393-412; L.G.Sharp, 'Walter Charleton's Early Life ...' op.cit., 335-339.
2. For the circle at Trinity College, cf. R.G.Frank, 'John Aubrey, F.R.S., John Lydall ...' op.cit., 194-195.
3. List given in draft copy of Petty's letter to ? John Owen, undated, at B.M. MSS. Volume 3, no.15, f.14 v. For these medics at Oxford cf. Burrows, Register of the Visitors, op.cit., pp.484, 158, 165 (Baber): 488, 529 (Maplett). W.Munk, The Roll of the Royal College of Physicians of London (London, revised edition, 1878), i, 379-382 (Lower); 338-342 (Willis).
4. Wren's career closely approximated to Petty's. An early involvement with natural philosophy was continued and transferred to later architectural interests, in the same way as Petty's involvement was extended to economics. Due to similar inventions, and aims, the two might have become competitors at Oxford, had Petty not left in 1652. For these similarities cf: C. and S.Wren, Parentalia, (London, 1750), pp.198-199; J.A.Bennett: 'Studies in the Life and Work of Sir Christopher Wren' (Cambridge University, Ph.D. Thesis, 1974); H.M.Jones, 'Sir Christopher Wren and Natural Philosophy with a Check List of his Scientific Activities' Notes Recs. Roy. Soc., 13 (1958), 19-37.

Restoration.[1] Also, a significant number of close friends from later life, notably John Aubrey, Peter Pett, and Robert Wood, initially met, or heard of Petty, as a result of this Oxford link.[2] His years at the University therefore influenced Petty in two fundamental ways: his prestige was enormously enhanced, and he met people interested in science who were to become life-long associates. In addition, his understanding that natural philosophers would benefit from working in an environment organised to promote joint endeavour and the exchange of ideas, was reinforced and broadened by this brief, but common experience.[3]

Even though his own work at Oxford produced no lasting or memorable scientific advance, it was still typical of the scientific interests shared by Petty and his colleagues. When he came to the University Petty was well qualified to take an important role in these pursuits. With broad experience of recent developments in continental physics, a thorough training at one of Europe's leading medical schools, great expertise in anatomical and clinical procedure, extensive technological skills, and his innate intellectual capabilities, he naturally assumed joint leadership of the scientific community. Thus, when Wallis stated that the meetings were first held in his lodgings (at 106, High Street[4]) this reflected the fact that not only were Petty's rooms con-

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1. Purver, op.cit., pp.119-120. For the effect of universities on the development of England's scientific community, see R.G.Frank, 'Science, Medicine and the Universities of Early Modern England: Background and Sources', Hist. Sci., 11 (1973), 194-216 and 239-269.
2. For Aubrey cf. M.C.W.Hunter: John Aubrey and The Realm of Learning, (London, 1975); for Pett see D.N.B, and references below; for Wood see D.N.B.; T.C.Barnard, Commonwealth Ireland, op.cit, pp.222-223; Webster, Instauration, pp.416-420; see Chapter 3, pp. 332-3. below, and Appendix 3, vi.
3. Petty may have strengthened Wilkins' resolve to found a 'College for Experiments', or 'Chymico-Mathematico-Mechanical School' in 1652. These plans resemble those advanced by Petty in the Advice (1648), and later to reform the Royal Society, see below, p. 158 ; Purver, op.cit, 109-110; Webster, Instauration, pp.171-2.
4. Purver, op.cit., 118-120.

veniently situated above an apothecary, but also that he was recognised as one of Oxford's foremost natural philosophers.

Petty fulfilled, with admirable efficiency, his official role as lecturer in anatomy. An early indication of this competence was given, when, though dispensed from the task, he nonetheless read the six lectures required by Laudian statute for those admitted as a D.M.[1] These public exercises reflect the training he had received at Leyden.[2] They covered the history and aims of medicine, the need for chemical therapy, and some more traditional subjects such as fevers and hysteria. Petty's medical diary shows that he implemented this theoretical approach in his own medical practice.[3] This exemplified his rejection of the radical dogmas of Paracelsus and Van Helmont, which were then helping to transform the medical world in London. Instead, he utilised herbal and, where appropriate, chemical remedies, with equal willingness. These notes establish that he supported traditional medical therapy, but was willing to include innovations in his practice if they appeared beneficial after clinical experiment. Such considered, experimental catholicity, was further exemplified in the 'Oratio inauguralis anatomica'[4] which he delivered in the Public Schools on 4 March 1651. In early spring he followed this with five lectures on the cadavar, complying with the requirements of the Tomlins bequest.[5] He gave another anatomical lecture in July,[6] and in the autumn three further lectures

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1. See Frank, 'Oxford and the Harveian Tradition ...' op.cit., i, 259-278 and ii, Appendix D, 793-797. Lectures at B.H. MSS. Volume 3, items 1, 3, 7.
2. See above pp. 22-29.
3. Notes at B.H. MSS. Volume 3, item 6, paginated 1-38. Periods covered: March - August, 1650/July - November, 1651. Detailed notes on ailments + prescriptions. Such diaries were common in the seventeenth century. See, Brit. Mus. Sloane MSS. 1949 'Dr. N.Grew: Medical Prescriptions' or Powers' memorandum books, containing his prescriptions, at Brit. Mus. Sloane MSS. 1351, 1353-1358.
4. At B.H. MSS. Volume 3, item 27.
5. B.H. MSS. Volume 3, item 4.
6. B.H. MSS. Volume 3, item 26. 'Lectio anatomica proemialis habenda In acta publico Oxonii 1651'.

on bones, later described in his list of writings as 'Three Osteological Lectures, 1651'.[1]

These lectures marked a notable break with tradition in Oxford's medical school. Derived from Petty's early training, they provided the most thorough, and certainly the most modern, instruction in anatomy and its associated medical subjects yet delivered in the University. The overriding feature of the lectures is their determined support for Harvey's doctrine of the heart's pump-like motion and the circulation of the blood. Petty's lecture in July 1651 started with a poem praising Harvey's work.[2] Significant parts of that autumn's course on the cadavar discussed respiratory function, theories of cardiacal motion, and the difficult problem of the origin of the blood. Petty's treatment of these questions was generally practical, being based on anatomical evidence, but where the situation required theoretical analysis of corporal phenomena he usually gave mechanistic explanations.

It was this question that caused Petty to give a succinct description of his view of epistemology and phenomenology. This was entirely consonant with previous statements, his earlier schooling in logic, and Baconian natural philosophy:

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1. B.H. MSS. Volume 3, possibly items 26, 27, 28 and 30. Lectures recorded in Petty's list of writings as '3 osteologicall lectures', Lansdowne, Petty Papers, ii, 261.
2. B.H. MSS. Volume 3, item 26. See C.Webster, 'William Harvey's Conception of the Heart as a Pump' Bull. Hist. Med., 39 (1965), 508-517; idem, 'Harvey's De Generatione: Its Origins and Relevance to the Theory of Circulation' Brit. J. Hist. Sci., 3 (1967) 262-274; idem, 'William Harvey and the English Harveian Tradition', private paper. Petty generally adopted Harvey's earlier attitude (De Motu Cordis, 1628) to the heart, as an independent, self-activating, motive force. Petty's extensive, but almost illegible anatomical manuscripts, require more detailed investigation before the intricacies of his view are clarified. For a survey of Harveian studies, cf. R.G.Frank 'Harvey Redux : Essay Review,' J.Hist. Biol., 5 (1972), 189-204.

> That as few as possible of insensible things, and such as cannot be examined by experiments, bee supposed.
>
> That if there bee, their nature in all qualities may bee described in a sensible manner.
>
> That nothing bee supposed impossible or absurd.
>
> That the supposition bee simple & short, & easily intelligible.
>
> That it solve all the phaenomena.
>
> That from it nothing may follow but what appeares.
>
> That as many such severall suppositions as possible may bee found out & the most suitable retayned.
>
> That none of all the suppositions made upon divers matters may disagree and bee inconsistent one with another.
>
> That having made suppositions of matters of many different natures, some principles bee afterwards drawne from them all, which were common to all the said suppositions and dispersed in them.
>
> That we find out sensible effects which are produced of sensible and cleere causes, very like unto other sensible effects begott from insensible causes. 1

Made with reference to medical prognosis, this attitude was consistently applied throughout the more speculative areas of Petty's natural philosophy. Thus, while preferring to restrict analysis to experimentally verifiable information, if such data was unavailable Petty was prepared to consider hypotheses providing universal explanations of the observed phenomena. As a statement of scientific principle it allies him both with Baconian empiricism and with continental hypotheticalism. Furthermore, Petty's subsequent comments in 1674[2] establish the fact that he adopted this approach throughout his life.

Nonetheless, his fundamental view of anatomy rested on a few select considerations: medical science was only as old as the science of anatomy, which itself dated from the work of Vesalius, one hundred and fifty

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1. B.H. MSS. Volume 3, item 15(a) 'The practise & Theory of pharmacy ...' M.S. scheme for medical essay, undated, but c.1651, printed Lansdowne, Petty Papers, ii, 167-168. This resembles the technique of Suarez, described above, pp. 10-13. For similar statements by Boyle, see: R.S.Westfall, 'Unpublished Boyle Papers Relating to Scientific Method - ii' Ann. Sci., 12 (1956) 113-117.
2. See below Chapter 3, pp. 330-335.

years earlier. Anatomy was the most certain part of medical knowledge. All animal limbs worked on mechanical principles: 'nor can any man take a better course to find out curious and usefull engins then by takeing the bodyes of animalls for his Piece and Pattern'.[1] Comparative anatomy was enormously useful and illuminated many obscure problems. Above all, he stressed that the only sure course to certainty was through experimental observation:

> 'Gentlemen, the th[o]rough knowledge of the fabrick of animals is not to be attained from the publick and promiscuous Demonstrations from a Theatre, nor from any wordy and tumultory discourses that can be made about it; but from curious and minute Disections made ... from various insufflations of wind, injection of Liquors, Severall colours and consistansies, by various ligatures and transfugions, and by severall Desications, excarnations of membranes and parenchimas; and not by looking upon things at a great distance and in transitue, but by poreing upon microscopes, upon small particles illuminated by extraordinary helps'. 2

In 1652, through his public anatomical and medical work, Petty emerged as an outstanding figure in Oxford natural philosophy. This local notoriety was also enhanced by the spectular exploit of Petty, Willis, and other medics, in reviving Anne Green after her public execution by hanging.[3] A number of pamphlets printed in Oxford and

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1. Petty summarised his views on anatomy in the Dublin Lecture of 1676. Located at B.H. MSS. Volume 3, item 25, printed Lansdowne, Petty Papers, ii, 171-179. Cf. ibid, 172.
2. Ibid., 173. This mirrors Bacon's statements in The Great Instauration, cf. Works, pp.246, 250, and 484-486. See also: E.A.Underwood, 'The Early Teaching of Anatomy at Padua with Special Reference to a Model of the Padua Anatomical Theatre', Ann. Sci., 19 (1963), 1-26.
3. For this exploit cf. Sir W.Osler: Bibliotheca Osleriana, (Oxford, 1939) pp.499-500, for pamphlets by R.Watkins, W.Burdet et.al, c.1650-1651. Williamson, Wren and Pope wrote poems celebrating the event which Watkins published in Newes from the Dead. Petty's own 'History of the Magdalen' is at B.H. MSS.37, Box H 'Royal Society', folder 15, (i), and at Lansdowne, Petty Papers, ii, 157-167. His therapy for Anne Greene was almost entirely non-chemical, utilising traditional methods such as bleeding, and classical pharmaceutical products like Tamarind and Alkermes.

London spread knowledge of this remarkable event, and Petty wrote to Hartlib on 16 December 1650, that:

> 'Thousands of people came from all parts to admire the great and powerful hand of God: in this busines ... My endeavours in this business, have bettered my reputation'. 1

Petty's display of conspicuous medical skill was matched in private by further examples of virtuosity. In the same letter to Hartlib, of December 1650, Petty reported his joint activity with 'The Club' in testing the hydraulic and pneumatic power of 'Captain Bulmer's experiment', where heavy weights were lifted by a bladder, under varying circumstances. In keeping with his fundamental attitude to such work, Petty reported that:

> 'After these experiments fully made and often wee had large and various debates about the reason, but I cryed out for the application thereof to some usefull thing'. 2

Another report of his activities was sent by Lydall to John Aubrey, the following May:

> 'Here have been some late inventions with us of some new engines, one is how to set a field of corne as soone as other waies it can to sowne & [a harrow] invented by Dr Petty but not yet altogether compleated. Another is how with ye same weights to weigh graines & scruples, & dramms, & ounces, both the scales & weights hanging slid at an aequall distance from the centre of the ballance, invented by MR Wren a Bac. of arts of Waddham, who likewise invented another engine for double writing'. 3

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1. Letter, dated 'Oxford ... 16th December 1650', copy, at Yale University, Osborn MSS. 63/4. Another copy at Hartlib Papers, viii, 23, ff.1-2.
2. Ibid, f.2r. Letter endorsed 'Dr Petty's Letter ab[ou]t blowing a boy or boat over London Bridge'. This experiment suggested stimulating parallels with the expansion of muscles. Cf. R.Hierons, A.Meyer 'Willis's Place in the History of Muscle Physiology' Proc. Roy. Soc. Med., 57 (1964), 687-8.
3. Bodleian Library, MS. Aubrey 12. f. 308r.

Just as with anatomy and medicine, Petty once again continued to capitilise on his previous work and training in natural philosophy. Another area where his skills were in demand was chemistry. Early in 1651, Hartlib reported in the Ephemerides that the Oxford 'Clubmen' had called on Petty 'to write the History of Concoctions, with some other pensa',[1] as his contribution to the general work of cataloguing and codifying existing knowledge in 'naturall philosophy and mixt mathematics'.[2] Petty was also asked 'to make medullas of all authors in reference to experimental learning'.[3] His ability to carry out these requests cannot be doubted. For example, his medical notes contain papers which establish his complete familiarity with many practical aspects of chemistry, including distillation, filtration, purification by washing and crystallisation, and the extensive use of basic laboratory equipment such as retorts, and sand and water baths.[4] The production of purified 'simples', or single chemical

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1. Hartlib Papers, MS. Ephemerides, 1651 A-B2.
2. Cf. H.W.Robinson, 'An Unpublished Letter of Dr Seth Ward relating to the Early Meetings of the Oxford Philosophical Society', Notes Recs. Roy. Soc., 7 (1950), 68-70. Ward mentioned that the 'Clubb' consisted of '30 persons' who were compiling a Baconian natural history on this type of natural philosophy. This corroborates Langbaine's ms. notes. Ward also noted: 'Besides this Greate Clubb we have a combination of a lesser number, viz: of 8 persons who have joyned together for the furnishing an elaboratory and for makeing chymicall experiments wch we doe constantly every one of us in course undertakeing by weeks to manage the worke'. This was probably Petty's group, or its continuation. Letter dated 27 February, 1652.
3. Hartlib Papers, MS. Ephemerides, 1651, A-B2.
4. Notes on chemical procedures at B.H. MSS. Volume 3, item 10. paginated 1-36. Petty's thorough training in practical chemistry was gained at Leyden, cf. Lansdowne, Petty Papers, ii, 261: '1645: An history of 7 monthes practise in a Chymicall Laboratory: [Holland]' This knowledge of Dutch chemical technology fitted Petty for work as an industrial chemist (1646-1650) and as an effective, 'modern' medical practitioner. For Evelyn see: F.S.Taylor: 'The Chemical Studies of John Evelyn' Ann. Sci., 8 (1952), 285-292. Power also kept similar records, cf. Brit. Mus., Sloane MSS. 496, ff.42-98.

agents, increasingly important for medical therapy and chemical research, was another skill that Petty (like Evelyn) had derived from early continental (Leyden) experience.

Petty's previous education therefore played a crucial role in his eventual success at Oxford. His medical skills, his intellectual and scientific virtuosity, and his pronounced empiricism, all ultimately depended on deep involvement with English and continental natural philosophy. Without his early training in France and Holland, and without the disappointing but constructive years in London, Petty's meteoric progress would have been impossible. Although the scientific work carried out at Oxford was at first unsophisticated, it stimulated ideas and interests which led to notable developments over the next thirty years.[1] Equally significant were the personal links and associations which many of England's leading natural philosophers built up during their early academic careers. Petty was influenced by these factors, and in turn influenced the axis adopted by Oxford natural philosophy between 1650 and 1652. Younger men like Wren and Sydenham,[2] and colleagues like Boyle and Willis, may also have benefited later on from his contribution to the character and vitality of Oxford's scientific community. For his part, Petty's triumphant academic progress enabled him to pursue his own ambitious, non-academic path.

The intention to forsake Oxford's settled, but scientifically creative climate occurred to Petty soon after his arrival. His ambitions centred on the previously rebellious, but now quiescent colony of Ireland.

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1. An example of such work was experimental transfusion: cf. C.Webster, 'The Origins of Blood Transfusion : A Reassessment' Med. Hist., 15 (1971), 387-392.
2. For example, Sydenham's knowledge of anatomy, utilitarianism and belief in clinical training may well have been strengthened by contact with Petty. cf. D.Ogg: England in the Reign of Charles II, (Oxford, single volume reprint, 1967), p.724; K.Dewhurst, Dr. Thomas Sydenham (1624-1689) His Life and Original Writings, (Wellcome Hist. Med. Lib., London, 1966), p.17.

In leaving, Petty deliberately rejected the University's powerful institutional appeal and the attraction of natural philosophy as practised by Wallis, Wilkins, et al.[1] As with Paris, he left a thriving centre of enquiry for the uncertainties of a disrupted, and scientifically retarded, environment. Once again, his reasons were clear and consistent: in 1651 he believed that Ireland offered him a chance to combine technical skills, scientific interests, and opinions about government and society in a way which greatly benefited his own career. The great difference between 1651 and 1646 was that his newly acquired academic prestige promised an excellent chance of success. Furthermore, his skill and reputation as a doctor provided an immediate route to his ultimate goal.

By combining all the fragments of information on his whereabouts between 1650 and 1652, it becomes clear that Petty's residence in the University was intermittent. For example, he was in London between May and September 1650 (medical diary), back there in February and March 1651 (election to Gresham College), and resident at Gresham during the summer and early autumn of the same year, when he met with a wide range of people including Hartlib, Dury and Haak.[2] Throughout this period Petty energetically petitioned influential personalities for their support. In a letter to Samuel Hartlib, of October 1652, Petty made familiar reference to Sir Henry Vane and 'our [other] friends at St. James', adding:

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1. See Wallis's description of this activity in Scriba: 'Autobiography ...' op.cit., 40.
2. Petty's presence at Gresham c. September 1651 is established by his signature, dated 1 September, in a commemorative album for Dr. Christopher Arnold, at Brit. Mus. Egerton MSS. 1324: f.108; address given as 'Ex Collegio Greshamaeo'. Other material derived from Petty's account with Brasenose College is at B.H. MSS. Volume 8, no.47. For contact with Hartlib et. al. cf. T.Barnett, Theodore Haak, op.cit., pp.93-94.

> '... for gods sake Omitt not to present my humblest service to my Lady Ranelagh. MR Sadler Mr Dury Mr Pell wherein thanke [them] affectionately for all their Care of mee ...' 1

Lady Ranelagh was a key figure in the strong Irish faction of that period, Vane was still an important member of the administration, and John Dury exercised considerable influence.[2] Although he undoubtedly solicited the goodwill of other notables, the few mentioned here give some idea of Petty's level of operation.

As early as 18 April 1651, Petty was granted permission by Brasenose and the Visitors to travel in service of the Commonwealth, while still retaining his stipend and fellowship.[3] By May of the following year the exact nature of this service was clarified: Petty was given an affidavit by the Council of State appointing him physician to the Lord Deputy of Ireland, with the handsome salary of £365 per annum.[4] This was not, however, his primary aim:

> '... he was recommended to the Parliament [... circiter 1651] to be one of the Surveyors of Ireland to which Employment Capt. J.Graunts interest did also helpe to give him a Lift and Edmund Wyld Esq. also then a member of Parliament and a great fautor of Ingeniose & good men for mere meritt sake (not being formerly acquainted with him) did him great service which perhaps he knows not of'. 5

Once again, his medical skill and intellectual 'meritt' recommended him to influential men. Petty's exploits at Oxford, his reputation as a brilliant young natural philosopher, his technical expertise, and his

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1. Yale University, Osborn MSS. 63/4, letter dated, 'Kilkenny, Octob.23.'
2. For Lady Ranelagh cf. Webster, 'New Light ...' op.cit., 28-31. For Vane cf. D.N.B.
3. Burrows, Register, op.cit. p.335.
4. Located at B.H. MSS. Volume 8, no.48, dated 10 May, 1652, addressed to, 'ye Ld: Deputy of Ireland and the Com[misione]rs of Parliam[en]t; there'
5. Aubrey's account in Keynes, Bibliography, p.87.

political moderation, made him a suitable candidate for preferment at a time when there was intense governmental demand for effective administrators. The Oxford years, therefore, mark the turning point in his career, though they contain as many elements of continuity, as of discontinuity. In leaving the University, Petty relinquished his close association with English natural philosophy, yet the Irish experience refined his early interests, broadening their range and capability. Although he was extremely critical of the Universities, he derived enormous benefit from Oxford, and, despite his contempt for its educational programme, energetically developed the medical course there. Finally, personal contacts from this period were soon neglected, but they revived after the Restoration, drawing him back into London's community of natural philosophers so that he became a founder and life-long supporter of the Royal Society.

Petty's new geographical location marked a watershed in his career: in Ireland he spent at least twenty-one of the remaining thirty-five years of his life; the country endowed him with riches, but also distracted him with the minutiae of government, and then with endless, exhausting law suits; it gave him the necessary experience of administration and surveying, expanding his view of Baconian natural history until it became a potent tool for reform, but changed political circumstance then denied him the chance to develop these powerful techniques in practice. Because the scope of his work altered so radically after 1652, it would be redundant for the present study to continue with a detailed account of all his subsequent activities. Instead, those which illuminate the development of his natural philosophy will now be sketched in, so as to provide a framework for a more thorough treatment of some of his central ideas.

(f) Ireland : Government and Survey, 1652-1660.

When Petty arrived in Ireland, his prime purpose was to take part in the government's survey of Irish lands.[1] It is well known that he gained control of the project by the end of 1654, and that, by the beginning of 1656, he had produced one of the most original, comprehensive, and accurate surveys ever attempted.[2]

This whole segment of Petty's life, given the undoubted significance of the 'Down' Survey, has received extensive coverage from historians. With the publication of basic documentary material by Larcom, and the massive work by Goblet,[3] a major step forward in interpretation took place.

Other analyses have helped place Petty's work on the Survey, and his later cartographic exercises into the correct perspective.[4] Three more

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1. B.H. MSS. Volume 3, No.15, f.1.r, fragmentary list of Petty's proposed activities, undated but c.1651/1652, '... to be informed of places ... to get acq[uaintances] ... Then London for August there to sollicite [the] Land busin[ess]' Lower in the list, the names 'Stapleton, Pride, Sir John Holland,Vane' appear. Further evidence of his intention to go to Ireland for this purpose comes from his address at the Grocers' Hall, November 28, 1658, 'the chief end of my going to Ireland was to make way for distinguishing the soldiers' from the adventurers' interest in the eleven counties.' Cal. State. Pap. Irel. Adventurers for land, 1642-1659, (London, 1903), p.362.
2. E.Lynam, British Maps and map-makers, (London, 1944), p.33, 'the most comprehensive and scientific survey of a large area made by any Englishman before 1755'. For the Dutch background see R.A. Skelton, Decorative Printed Maps of the 15th to 18th Centuries (London, 1952), pp.58-65.
3. For the edition by Larcom, and the work by Goblet, see above p. iv, n. 1 and p. iii n. 3.
4. cf. Fitzmaurice, Life, 23-68; Strauss, Sir William Petty, pp.43-90; J.H.Andrews: Introduction to Hiberniae Delineatio ... and ... Geographical Description of Ye Kingdom of Ireland ... (Shannon, Ireland, 1969); S.Matsukawa 'Origin and Significance of Political Arithmetic', Ann. of Hitotsubashi Academy, 6 (1955), 53-79; Andrews, op.cit., pp.21-23, gives an excellent bibliography.

recent works[1] have added to our understanding of the detailed context of Irish intellectual life between 1652 and 1660, and of the Survey's role as an extension of Baconian and reformist programmes for comprehensive natural histories of specific geographical regions. As a result of such attention, this section of Petty's biography will attempt merely to summarise the details of this part of his career in order to show that the Survey represented a natural development of his existing interests, and to illuminate its effect on his conceptual approach to natural philosophy. Through this analysis it will be seen that in meeting the organisational and technical challenges of the Survey, Petty was utilising techniques and attitudes derived from his earlier training, and in the process underwent a mental change which raised his understanding to an altogether higher plane.

Petty arrived in Ireland during October 1652. At this point the country lay devastated and depopulated, the result of a decade of war and disease. Despite this 'barbarous' condition, Ireland seemed to several reformers, a potentially fertile and productive country. Robert Wood exemplified this belief when he wrote to Hartlib, in November 1656, that:

> '... only this I shal say, that if Englishmen were perswaded how richly this island even the worst parts of it are furnished wth conveniences for life, they wood not stay at home and live so poorly as many of them do ...' 2

This attitude, which viewed the country as an ideal location for

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1. Webster, Instauration, pp.427-444; Barnard, Commonwealth Ireland, pp.213-248, 'The Advancement of Learning;' idem, 'The Hartlib Circle and the Origins of the Dublin Philosophical Society' Irish Historical Studies, 19 (1974), 56-71. For further bibliographical references see Webster, Instauration, p.436, n.291.
2. Hartlib Papers, xxx, 1, f.7.r, 23 November, Dublin-London. Hartlib had long held similar expectations, cf. S.H. His Legacie : Or an Enlargement of the Discourse of Husbandry, (Sec. ed., 1652) p.32, 'I hope in a little time Ireland will furnish us with those commodities...'

rational economic development, had gathered momentum over the previous decade: concrete expressions of this belief were provided by the Boate brothers, and by Samuel Hartlib, who published Gerard's, Irelands Naturall History,[1] and appended Arnold's questionnaire, An Interrogatory Relating to ... the Husbandry and Naturall History of Ireland, to the second edition of his Legacie of Husbandry, (1652). Behind these publications lay the conviction that a full and accurate picture of a country's shape and resources (a geographical natural history) was the essential prerequisite for social and economic development.[2] Derived from the Office of Address, and the Baconian dictum on empirical collection of data, procedural methods for such information-gathering were, from the start, impressively scientific and comprehensive.[3] Thus the reformers maintained that once this exact description of Ireland was complete, the country's inherent agricultural and economic potential would become self-evident, and this would encourage rapid development on the part of government and private enterprise.[4]

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1. G.Boate, Irelands Naturall History. Being a true and ample Description of its Situation, Greatness, Shape, and Nature, ... of its Fruitfull Parts and profitable Grounds, with the Severall ways of Manuring and Improving the same. (London, 1652). Hartlib also published Cressey Dymock's short essay, A Discoverie for Division or setting out of Land ... for Direction and more Advantage and Profit of the Adventurers and Planters ... in England and IRELAND, (London, 1653). Child enthusiastically reported to Hartlib, 29 August, 1652, '... I believe there is scarce any place in the land, where men are made more active in fencing, drayning, dunging and Improving their land ...', Hartlib Papers, xv, 5, f.14r.
2. See letter Boyle to Clodius (Hartlib's son-in-law). Boyle, Works, (1772 ed.), vi, 55, undated, but c. May 1654, '... an officer of the army, who farms a silver mine from the State, who hath promised me what assistance he can in my mineral enquiries ... told me, that [an excellent] metallist and refiner ... assured him, that there was no country in Europe so rich in mines as Ireland, had but the inhabitants the industry to seek them, and the skill to know them'. G.Boate was also scathing about the Irish inhabitants. Cf. Chapter XIV, Section 2, Irelands Naturall History, 'Retchlessness of the Irish, cause of most ... bogs'.
3. For the scientific innovational methods of Irelands Naturall History cf. Barnard, Commonwealth Ireland, pp.214-215, 226; idem, 'The Hartlib Circle [in Ireland]' op.cit., 58-59. Webster, Instauration, pp.429-431.
4. Cf. letter Hartlib to Boyle, 8 May, 1654, in Boyle, Works (1772 ed.) vi, 84 and 87-88.

With this clear vision directing his actions, Hartlib energetically supported the correction, and completion, of Irelands Naturall History. He systematically implored each of his contacts to take up the task, starting with Robert Child, Boyle, Petty and Worsley, and turning later to Symner and Wood, as death, or other less fatal events successively distracted those colleagues.[1] Unfortunately, the natural history, at least in the form envisaged by Hartlib, was never finished.

Petty's response to the demands of Hartlib and Child,[2] was entirely consonant with his basic attitudes, and the more massive and immediate problems facing the government in Ireland. Consequently, besides a short, general section in one of his occasional letters to Hartlib, he contributed nothing to the reformer's private project.[3] Instead, he became involved with the more practical requirements of the situation in Dublin. His first task was to solve a pressing problem for the army medical corps: the supply of equipment and pharmaceutical products:

> 'the Said Dr had not been landed two moneths, but, observing the vast and needless expence of medicaments, and how the Apothecary-Generall of the army, with his three assistants, did not spend their time to best advantage; did forthwith, to the content of all persons concerned, with the State's bare disbursement of about 120 save them five hundred pounds per annum

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1. See Webster, Instauration, pp.432-4 and Barnard, Commonwealth Ireland, pp.234-237.
2. Child wrote to Hartlib on 2 February, 1653, Hartlib Papers, xv, 5, f.18r. eagerly noting his first contact with Petty, and his request to the Doctor that he ... 'take notice of whatsoever worth the observation occurreth'.
3. Yale University, Osborn MSS. 63/4, letter dated Kilkenny, 23 October, 1652. Petty refers to the 'few and confused' observations, apologises for their paucity, and promises further comments. These were not forthcoming, since he was diverted by other matters, and, despite his comment 'that I doe not forgett my friends', his letters to Hartlib became infrequent.

> of their former charge, and furnished the army, hospitalls, garrisons, headquarters, etc. with medicaments, without the least noise or trouble, reducing that affair to a state of easiness and plainness, which before was held a mistery, and the vexation of such as laboured to administer it as well.' 1

Petty's immodestly-recorded action has hitherto been regarded as significant, only in so far as it illustrates his confident powers of organisation.[2] In fact, this interlude gave him his first opportunity to exercise and develop those powers: the reformation of such a complex, disorganised system called forth new managerial skills and for the first time he exercised the authority that went with a senior government post.

In solving these organisational problems, he did not forget the prime reason for his journey to Ireland. Following up his earlier works with dialling[3] and surveying, '... for which the said Dr had formerly gained some reputation in the world',[4] Petty continued to experiment and develop new techniques in this complex and topical art:

> 'I hope Major Morgan hath told you how hee hath provoked [me] to study dialling, Even to ye producing of an Easy practicable Invention to doe more than I can finde written in all ye Kirchers, Bettinus or other great pretenders, indeed as much as I can well conceive to be possible in that Art. Wee can thereby convert any Vast Roome into a Vast Globe, making the same usefull to all purpose where unto so great a Globe can bee serviceable. A Treatise thereby shall perhaps ere long sue to bee admitted among your rarities.' 5

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1. Petty, History of the Down Survey, (ed., Larcom) op.cit. pp.1-2.
2. Strauss, Sir William Petty, p.55.
3. A 'dial' is defined in Chambers Dictionary, (London, 1964) p.288, as 'a graduated plate on which a moveable index shows the value of some quantity measured', or, 'a miner's compass with sights for surveying'. 'Dialling' in this instance, therefore, meant surveying by dial.
4. Petty, History of the Down Survey, op.cit., p.1.
5. Yale University, Osborn MSS. 63/4, letter Petty to Hartlib, dated Dublin, 29 January, 1654.

Hartlib later wrote to Boyle,[1] asking for details of this research. Petty's reply[2] indicated that he was completing this treatise, which summarised and systematised developments made jointly by Captain Morgan[3] and himself:

> 'I receyved your letter (among other things) desiring the communication of my dialling labour. The which I have so far hearkened unto, as to Write them in Lattine in about 10 sheetes of paper, but very succinctly, & intelligible onely to those that understand common dialling well already, and are handy in the practise of such things, for, otherwise I would make large Volumes of them ...' 4

Petty then reported that, since he was unsure of the exact progress made by other experts, he would not release the 'epitome' until enquiries had been made into the general state of the subject:

> '... although the things are all of my owne Invention, Though perhaps all may have beene done by others before, I promise you my willingness to put it out, & when I doe it, to doe by & through yo^{w} ...' 5

During the period between 1653 and 1654, Petty and Morgan therefore perfected their surveying techniques, through direct innovation, and by research into currently available methods and equipment. For his part, Petty was able to capitalise on skills acquired during his early training: the school of geography at Caen, Oughtred's noted expertise, association in Holland with a leading English surveyor like

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1. Boyle, Works, (1772 ed.) vi, 88, letter dated 8 May, 1654.
2. Yale University, Osborn MSS. 63/4, letter dated Dublin, 28 (?) June, 1654.
3. For Morgan see D.N.B. and Barnard, Commonwealth Ireland, p.223. Morgan was one of Petty's close friends at this time. cf. Petty, History of Down Survey, op.cit., pp.263, 267. Morgan also worked with Petty on the Survey, often acting on his behalf in negotiations with the government.
4. Yale University, Osborn MSS. 63/4, letter 28 June, 1654.
5. Ibid.

Dr. John Wybard,[1] and his own commercial development of instruments during the London years,[2] gave him a complete mastery of this developing technology. On completion of the Survey two years later, Robert Wood, himself an excellent mathematician, said of his new friend:

> 'Dr. Petty, tho a man very busy & much employed, is yt your servant. he perfectly understands ye businesse of ye Globe & being master of that Speculation & of an excellent witt and invention besides (as you know) is able to do as much in Dialling as I believe anyone ...' 3

Wood's comments indicate the mastery Petty had achieved by 1656. His existing expertise, combined with his dedication to the profitable application of his skills, allowed Petty to tackle the enormous problems which faced him in 1654, and, where other men might have been broken, to emerge successful two years later.

After Cromwell's subjugation of Ireland, English attention turned to one pressing concern: the need to realise assets bound up in forfeited Irish lands and thereby pay off a significant part of the national debt. This deficit had accumulated through substantial government borrowing from the Adventurers (to finance previous hostilities) and by deferral of payment to the soldiers, whose arrears were subsequently translated into debentures on Irish lands. After 1652, fiscal strains became increasingly severe on the administration, requiring it to disband the army. However, this could only take place after its pay claims had been settled. The government, therefore, needed to make an exact appraisal of the nature, extent, and productivity of confiscated Irish

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1. For Wybard see, E.G.R.Taylor, The Mathematical Practitioners of Tudor and Stuart England, 1485-1714, (London, reprinted 1970), pp.88-90, 212-213, and for Petty's link with Wybard in Holland, p. 35 above.
2. The advertisement for Petty's new dialling instruments and techniques is given in Appendix I, i, below. Hartlib noted, M.S.Ephemerides, 1654, RR-RRi, 'All books of dialling will bee useless when Dr Petty's invention on that subject will bee published.'
3. Hartlib Papers, xxxiii, 1, f.3.r + v, letter Wood to Hartlib, 10 June, 1656, 'the Phoenix, nere Dublin', to London.

estates, with their major buildings and fixed assets, so as to extract from them the maximum capital value with which to meet its financial commitments.[1] Two further aims were also kept in mind: the provision of accurate information on which future taxation could be based, and a rational organisation for the 'replanting', or colonial development of Ireland.[2]

In 1653[3] Benjamin Worsley was appointed Surveyor-General and given the crucial task of organising this massive project. His attempts, hampered as they were by inept instructions and undue pressure,[4] produced fairly comprehensive surveys of certain limited regions, incorporating lists of forfeited estates, with much additional economic and topographical information. Unfortunately, this process was expensive and far too slow to answer the mounting fiscal problem facing the government. It also failed to provide a cartographic basis for land distribution. In September 1654 Petty approached the Council with a set of startling proposals:[5] he offered to complete within thirteen months a survey of all forfeited lands earmarked for payment of the army. The resulting information would be 'layed down' in maps covering 'all known territorial boundaries, all the natural divisions of the country, whether rivers, wood, bogs or other', which would facilitate an immediate, accurate division of land amongst the impatient debenture holders.[6] Worsley henceforth raised objections to the plan, calling into question Petty's ability to put it into effect. In response, the younger man submitted details of his methods to the controlling committee. They were so

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1. Strauss, Sir William Petty, pp.56, 58. Matsukawa, op.cit., 68, 70-71.
2. For the government's requirements which called for appropriately detailed returns, see, Petty, History of Down Survey, op.cit., pp. 372-374.
3. Barnard, Commonwealth Ireland, p.220.
4. Petty, History of Down Survey, p.313.
5. Ibid, pp.9-10.
6. Ibid, pp.313-314.

clearly and confidently delineated that Worsley 'confest himselfe gravelled as to his objecting against the performance of soe vast a work in thirteen moneths, because he allways tooke it for a business of as many yeares'.[1] Petty was finally awarded the contract in December 1654, and proceeded with the survey in February 1655. Despite political opposition, the depradations of Tories, atrocious weather conditions, the jealousy of Worsley and other surveyors, incomplete information about forfeited estates, negligent and dishonest employees, fraudulent returns, and contractual requirements ill-suited to conditions on the ground, Petty completed the task, 'soe far as concernes my engagement', in March 1656.[2] He himself summarised this remarkable achievement as follows:

> '... the practises which I have used, ... as [a] Surveyor ... are such as I can glory in, that is to say, to have admeasured, as I told you, twenty-two counteyes in thirteen moneths time, with the chine and instrument; to have done this by the ministery of about one thousand hands, without any suit of law, either with my superiours or with them; to have maintained this survey stiff and stanch against the impugnation of some thousand diligent find-faults; to have freed my selfe and suretys by the consent and mediation of ffourty-five officers of the army ... to have assigned satisfaction for above twenty-thousand debentures in such a way as admitted of noe chopping and changing afterwards, and soe as a slight coppy out of our booke is accepted in courts of justice as a good evidence, meerly by virtue of the naturall justice and validity whereuppon it stands'. 3

In addition, the survey, which was extended after 1656 to cover a large proportion of the 'English' counties,[4] provides a basis for the first reliable cartographic representation of Ireland,[5] and hence for many

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1. Ibid, p.11.
2. Ibid, pp.331-334.
3. Ibid, pp.295-296.
4. Andrews, Introduction, op.cit. p.1.
5. Ibid, pp.10-11, 13. Strauss, Sir William Petty, op.cit, pp.72-73.

generations of accurate maps.

Petty's Down Survey was a remarkable undertaking: without it, the rapid redistribution of confiscated Irish lands, recently described as 'the major administrative and technical achievement of the Interregnum',[1] would have been impossible. Nonetheless, it should be realised that he was given very able assistance by other surveyors and mathematicians like Miles Symner, Henry Osborne,[2] and Benjamin Worsley.

At this point it would be useful to elucidate Petty's relationship with Worsley, because it provides a classic instance of competition between rival 'projectors'. Since both men were friends of Samuel Hartlib, government employees, Baconians, and outstanding practitioners of experimental natural philosophy, it might be expected that they would have co-operated enthusiastically in their pursuit of scientific and utilitarian ends. Unhappily this was not the case. Whereas Petty had previously vied with Kalthoff and Dymock[3] for pre-eminence as an inventor and technologist, accepting the mediation of Hartlib and Worsley, in 1654 he found himself competing against Worsley for a far greater prize. After Petty's successful criticism, and displacement of Worsley,[4] their relations became strained. In their letters to

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1. Barnard, Commonwealth Ireland, p.226.
2. For Osborne, A More Exact Way to Delineate the Plot of any spacious parcel of Land as Baronies, Parishes and Town-Lands ... (Dublin, 1654), published with government backing, cf. Barnard, Commonwealth Ireland, pp.228-229.
3. In a letter to Hartlib dated 'October 23, 1652' Yale University, Osborn MSS. 63/4 Petty rebutted accusations of hostility towards Dymock: '... present my humblest ... to MR. Dymock whose affaires I have promoted but Never in the least hindered & whom I have secretly and Openly praised never backbited Much lesse (as hath been insinuated) endeavoured to ruine'.
4. Ibid, Petty revealed an early, mutual distrust, referring to Worsley's 'Mistaken distast[e]' and 'strong ... Enmity'. His letter dated 9 March, 1654, ibid, outlines Worsley's unsuccessful attempt to discredit Petty among Lady Ranelagh's circle. Despite his obstructions, Petty was given the final contract to survey forfeited lands on Christmas Day, 1654.

Hartlib, each man complained of the other's deviousness and dishonesty.[1] Although collaboration on extending the Survey[2] led to an improvement in relations during 1655 and 1656, the following year they again drifted towards bitterness and hostility. Worsley's growing political extremism, increasingly mystical outlook,[3] and declining influence, were accentuated as Henry Cromwell's control over the administration levered sectarians from positions of power. All these factors fuelled Worsley's jealousy of Petty, who had not only supplanted him in directing the survey, but had also become an indispensable servant of Ireland's de facto ruler. For his part, Petty did everything he could to weaken his opponent's position and inhibit his activities.[4]

This bitterness, combined with Worsley's growing rift with the government, ultimately denied to the hard-pressed administration the services of this highly competent figure.[5] These factors were equally detrimental to the cause of Irish natural philosophy. Dissension among the adherents of the Baconian reformist programme imperilled the group's

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1. For the tenor of Worsley's comments cf. Hartlib Papers, xlvii, 3,ff. 1-4.
2. Petty's letter to Hartlib, dated 17 October, 1655, Yale University, Osborn MSS. 63/4 reports '... Sr I have written these few words to beg a letter from you, though MR Worsley has been pleased often to communicate yours unto Mee there is Not that distance between us that you may Imagine'.
3. For this mysticism cf. views expounded in 'Dr. Worsley's Physico-Astrological Letter,' 20 October, 1657 at Hartlib Papers, xlii, 1, ff.9-10, where Worsley's positivistic, utilitarian attitudes are more subdued, and his mystical, anti-rationalistic 'enthusiasm' is emphasised. See also: P.M.Rattansi, 'Paracelsus and the Puritan Revolution'. Ambix, 11 (1963), 24-32, especially 28; Barnard, Commonwealth Ireland, pp.20-25. For Worsley as Paracelsan see Hartlib Papers, xlii, 1, ff.5-6, letter dated 14 February, 1655.
4. For Petty's politically-motivated opposition to the scheme for an Irish agency for the advancement of learning see below p.141.
5. Barnard, Commonwealth Ireland, pp.221-222.

fragile coherence, thus limiting the progressive influence of Ireland's 'visible church of philosophers'.[1] By 1660 Petty's vituperation for Worsley knew no bounds:[2] he accused his opponent (with varying degrees of justification) of jealousy, incompetence, obstruction, religious extremism, fraud and ingraditude, of which the following is a representative example:

> 'Moreover when MR Worsley himself (who traded only in slights to become suddenly rich, as by the Universal Medicine, Making of Gold, Sowing of Salt-Peter, Universal Trade, Taking great Farms, etc) saw a fair opportunity taken out of his hands, and that all his Mountain-bellied Conceptions ended only in abortive Mice ... [he, along with many others] ... set themselves to throw blocks in my way, and to hang clogs at my heels, whereby to make my Merits and Fortunes no more considerable than their own ...' 3

These comments illustrate the sources of conflict between the two men, and (more subtly) of the various types of 'Baconianism' which simultaneously developed in response to forces and pressures not necessarily connected with either natural philosophy or utilitarianism. The dislocating effects of such intestine warfare partly explains the continuing lack of cohesion which debilitated English natural philosophy towards the end of the century. It reflects the weakness inherent in an institutionally and socially unsophisticated society: there did not exist the appropriate economic and organisational modalities to transmute this unproductive aggression into co-operation or healthy competition. In such a situation of underdeveloped institutional structures, the success of

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1. Described as such by Petty in a letter to Boyle, 15 April, 1653; Boyle, Works, (1772 ed.), 138.
2. W.Petty, Reflections upon some Persons and Things in Ireland ... (London, 1660), pp.14, 32, [henceforward, Petty: Reflections]. Cf. Keynes, Bibliography, 5. See also Petty, History of Down Survey, op.cit. pp.2-3.
3. Petty, Reflections, pp.106-107.

of one man could mean the exclusion and waste of another's talents. Later on in life, with greater detachment, Petty said:

> '... I gather you have not onely a great corrispondance with: Dr Worsley, but an intention to make use of him in our Irish concerns. To w<u>ch</u>: I onely give you this advertisement that I doe not know that Hee and I are perfectly Friends, for before his Ma[jes]ties: Restoration I was for a single person, he for an other forme, or for ye singule person Sr. Hen: Vane & perhaps these things are worn out, Hee is a person of very good qualification tho' perhaps not the fittest to give advice of Mee or my designes, and yet very capable to judge aright if hee pleases ...' 1

Nonetheless in 1654, with regard to the particular problems of the Survey, Petty's conceptual and logistical techniques were manifestly superior to those of Worsley. However, the development of these methods, and their underlying framework, did not suddenly materialise between 1652 and 1654. To argue that they evolved at this remarkable pace is to argue for an absolute discontinuity in Petty's intellectual growth.[2] This attitude is inaccurate, and fails to recognise powerful ideas which moulded Petty's view of natural philosophy from early in his career until the <u>annus mirabilis</u> of 1654. This statement may be clarified by a brief recital of the factors which linked the Survey to Petty's earlier experience and aspirations.

It will be remembered that in 1648 and 1649 Petty's burning ambition was to obtain state backing for grandiose schemes that would further the cause of Baconian natural philosophy, social amelioration and, incident-

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1. B.H. MSS. Volume 19, pp.72-73, letter, 7 December, 1672 Petty to Mr. Tomkins, a business associate.
2. Despite unusual perception, S.Matsukawa, 'The Origin ... of Political Arithmetic' <u>op.cit.</u>, 67, partially supports this view: 'Not long after his arrival in Ireland, he took over the task of surveying and distributing the confiscated lands, though it had little connection with his profession'. It is echoed by Barnard, <u>Commonwealth Ireland</u>, pp.218, 228, and by K.T.Hoppen, 'Sir William Petty: Polymath, 1623-1687' <u>History Today</u>, 15 (1965), 128.

ally, his own career. By 1652 it became obvious that the acute problems facing the government in Ireland presented him with a golden opportunity to gain control and execution of precisely this type of large-scale project. His technical skills, impressive reputation and capacious plausibility enabled him first to catch the attention, then the support of high-level officials comparable to members 'of the Council of State, or Parliament's leading grandees'. These 'states-men'[1] had, given the circumstances in 1649, quite properly disregarded his initial proposals, but were now willing to hand the problem over to Petty, once his detailed plans had been minutely scrutinised by experts, and the correct financial guarantees provided. In turn, the task's clearly defined parameters narrowed down his somewhat wild and vague ideas, allowing his brilliant talent for pragmatic organisation to come into play.

Secondly, Petty's deep appreciation of the Survey's implications was the product of a multitude of personal experiences, and also of the general intellectual climate. His education within the geographical school at Caen, his contact with de Laet at Leyden, the logical, collectivist techniques of Suarez, and the fundamental characteristics of medicine and anatomy (in terms of natural history) gave him a multidimensional understanding of the wider purpose and procedures of surveying. As will later become clear, Petty's choice of the phrase 'Political Anatomy' was not accidental.

In a more precise fashion he also benefited from two associated influences: Francis Bacon, the dominant philosophical luminary in Petty's life, had stated the case for economic and political surveys with characteristic precision and succinctness:

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1. See Hartlib's description of one such scheme in the Ephemerides for 1649, quoted above, pp. 84-85.

> 'The greatness of an estate in bulk and territory, doth fall under measure; and the greatness of finances and revenew doth fall under computation. The population may appear by musters; and the number and greatness of cities and towns by cards and maps. But yet there is not anything amongst civil affairs more subject to error, than the right evaluation and true judgment concerning the power and forces of an estate.' 1

Bacon's further thoughts on this subject with regard to correct governmental methods, and Petty's own views, will be discussed below. For the present, what is significant is the unmistakeable intent of this particular passage, and Bacon's general influence on Petty. Furthermore, this influence was re-affirmed and amplified in Hartlib's multitudinous schemes for an Office of Address. Petty's close association with this ever-changing project occurred exactly when the data-gathering possibilities of the agency were becoming clear to Hartlib and his associates. In 1648 Hartlib published A further Discoverie of the Office of Publick Address for Accommodations, the more specialised sequel to England's Reformation which had appeared the previous year. Petty, who deliberately composed the Advice as a contribution to this institutional programme,[2] could hardly have failed to recognise the import of the following statement, which occurred towards the end of A further Discoverie:

> 'He that can look upon the frame of a whole State, and see the constitution of all the parts thereof, and doth know what strength is in every part, or what the weaknesse thereof is, and whence it doth proceed; and can, as in a perfect modell

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1. Bacon, Works, pp.770-771, Essays or Counsels Civil or Moral, 'XXIX. Of the True Greatness of Kingdoms and Estates'. The Essays were published in Leyden in three editions, between 1641 and 1644, and Heereboord devoted partibular attention to Bacon in his lectures and published works. See abovepp.19-21.
2. cf. Petty, Advice, pp.1-2, and Sig.A3, and p.26, on Natural Histories.

> of a Coelestiall Globe, observe all the Motions of the Spheres thereof; or as in a Watch, See how all the wheels turn and worke one upon another for such and such ends, he only can fundamentally know what may and ought to be designed; or can be effected in that State for the increase of the Glory, and the settlement of the Felicity thereof with Power according to Righteousnesse'. 1

In 1654, regulation, distribution and national 'Felicity' were the precise and immediate requirements of the Survey, and these depended on a detailed knowledge of the 'frame of [the] whole State', or at least those sections which were to be used to cover the national debt.

All these experiential and intellectual factors moulded Petty's concept of the method and potential role of the Survey:

> '... Dr Petty propounded that the whole land should be measured both according to its civill bounds, viz., by barronyes, parishes, townelands, ploughlands, balliboes, etc., and alsoe by its naturall boundings by rivers, ridges of mountaines, rockes, loughes, boggs, etc; as answeringe not onely the very ends of satisfyinge the adventurers and souldiers then in view, but all such other future ends whatsoever as usually expected from any survey.' 2

When outlining this broad role for the Survey, Petty deliberately transcended the more restricted, contractual liabilities which had been agreed upon with Worsley and the government in December, 1654.[3] Even as it stood the contract presented a major challenge to Petty's ingenuity: it required incredibly rapid 'admeasurement' of all forfeited lands within the ten counties, whether profitable or unprofitable, for topographically discrete units of forty acres or more. This admeasurement

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1. Hartlib, A Further Discoverie, p.26.
2. Petty, History of ... Down Survey, p.xiv, 'A Briefe Accompt ... relatinge to the Survey managed by Doctor Petty in Ireland, anno 1655 and 1656'.
3. Ibid, pp.23-29.

was to be 'laid down' in 'exact mapps' to facilitate 'publique use[s].' The resulting 'platts' were to be provided with supporting 'books of reference', which enumerated ownership and the nature of each parcel of land. The government clearly intended, therefore, to utilise the survey, and any subsequent extension, for topographic, cartographic and cadastral purposes. Petty eagerly accepted this problematic brief and, with amazing confidence, stipulated far broader regulations for his own surveying teams. In his 'Instructions for surveying and admeasuring the forfeited and other Commonwealth Lands in Ireland'[1] Petty described the most ambitious set of surveyal requirements in terms of topography, geomorphology, economic geography,[2] cadastre and cartography, hitherto seen in Ireland, and possibly elsewhere. A supplementary set of notes underlined and explained the mathematical, geometric and cartographic methods, stating acceptable degrees of error with clarity and precision. Petty's conceptual view of the survey's value therefore transcended that envisaged in the immediate contract, and was a direct amalgam of many intellectual and personal factors.

However, what particularly distinguished Petty from other surveyors and natural historians (including Worsley), was a combination of this vision with an unusually creative talent for solving logistical problems, and for developing simplified but effective technology. One source of Petty's superior method was most obviously derived from another fundamental Baconian concept. This called for specialised teams of trained workers, operating within a coherent organisational framework which integrated the results of their collective, and collect-

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1. Ibid, pp.46-53.
2. The heading of 'economic geography' covers Petty's detailed requirements for descriptive notes, and exact cartographic records, of rivers, highways, industries, important buildings, types of agricultural usage with topographical dispositions, natural landmarks, harbours, coastal soundings, and islands. These subject divisions closely resemble those in Boates Irelands Naturall History.

ivist, efforts. The inductive method, so clearly described in Novum Organum, De Augmentis and New Atlantis was intended to be ' ... such as leaves but little to the acuteness and strength of wits, but places all wits and understandings nearly on a level'.[1] Bacon constantly reiterated his belief that major advances in natural philosophy depended more on correct scientific and organisational methods, than on individual genius. Nonetheless, these logical and logistical procedures obviously required direction by an overall controller. He had to possess sufficient skill and insight to maximise the effectiveness of discrete units within the system, ensuring that integration of their co-operative endeavour, following methodologically appropriate lines, would produce the desired result:

> 'Nevertheless as a man may proceed on his path in three ways: he may grope his way for himself in the dark; he may be led by the hand of another, without himself seeing anything; or lastly, he may get a light, and so direct his steps; in like manner when a man tries all kinds of experiments without order or method, this is but groping in the dark; but when he uses some direction and order in experimenting, it is as if he were led by the hand; and this is what I mean by learned Experience. For the light itself, which was the third way, is to be sought from the Interpretation of Nature, or the New Organon'. 2

New Atlantis gave a concrete example of this intellectual and methodological process when describing the communal efforts of expert scientific teams working in Solomon's House.[3]

Owing to a mixture of good fortune and skill, control of the Survey allowed Petty to put these hitherto untried ideals into practice. In

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1. Bacon, Works, (Novum Organum) Book I, p.270, (Aphorism LXI). For a repetition of this view cf. ibid, Book I, p.297 (Aphorism, CXXII).
2. Bacon, Works, (De Augmentis), p.505.
3. Bacon, Works, (New Atlantis), pp.730-731.

the debate with Henry More[1] he had already expressed the Neo-Baconian view that scientific procedures should allow men 'of a meane capacity ... [to] be able to foretell the effects of nature by them before they happen'. He agreed that by broadening the base of popular involvement in natural philosophy, its previously slow and painful progress would be accelerated. However, quite apart from Bacon's general analysis of the scientific application of 'division of labour' Petty had also witnessed various systems, employing specialised workers, operating in several Dutch industries,[2] on board sailing vessels,[3] and in the instrument manufacturing trade, with which he had become involved when trying to exploit his double-writing, and dialling equipment.[4] Thus, when presented with the Survey's massive challenge, Petty's innate genius for translating concept and experience into organisational reality came into play. In what became the century's largest, most coherent and most effective display of collaborative Baconian research, the principle of the division of labour was rigorously applied at every level. Using Bacon's methodological dicta, and possibly his description of Solomon's

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1. See above, p. 59 paragraph 4.
2. cf. V.Barbour, Capitalism in Amsterdam in the Seventeenth Century (Baltimore, 1950), pp.67-69.
3. cf. R.Davis, The Rise of the English Shipping Industry in the Seventeenth and Eighteenth Century, (Newton Abbot, 1972), pp.111-122.
4. E.G.R.Taylor. Mathematical Practitioners, op.cit. p.68, 'Such a division of labour was very usual, and was a wise precaution, since however skilled a joiner or brazier or smith might be in his own craft, he might fail (and according to contemporary evidence he did fail) to appreciate what was meant by the precise division of a scale, or by incision of a line to a hair's breadth'. See also, Another Essay in Political Arithmetick, in Hull, Economic Works, ii, p.473, '... each Manufacture will be divided into as many parts as possible, whereby the Work of each Artisan will be simple and easie; As for Example, in the making of a Watch, If one Man shall make the Wheels, another the Spring, and then shall Engrave the Dial-plate, and another shall make the Cases, then the Watch will be better and cheaper, than if the whole Work be put upon any one Man'.

House as a broad template, Petty adapted these ideas to fit the unique, but scientifically less-sophisticated, demands of the immediate problem.[1]

Successive accounts of the Down Survey have itemised the minutiae of its organisation with a notable degree of consonance. The most recent description has also given a detailed analysis of the surveying techniques devised by Petty to facilitate the employment of relatively unskilled labour.[2] This section will therefore seek only to summarise these aspects of this great project, which embodied three distinct areas requiring his technical and organisational skills. Firstly, these were applied to simplification of the design and subsequent production of surveying equipment; next came the selection, formation, training, and operational procedures of individual surveying teams; finally there was the preparation of a central administrative organisation to co-ordinate operational field work, and process the raw data into those cartographic and cadastral forms stipulated in the contract. Initially, Petty had to proceed with the creation of all these procedures and systems simultaneously, rather than sequentially. It was fortuitous that he could rely on the assistance of a highly skilled team of principal surveyors and under-surveyors, which probably included Thomas Taylor, John Petty, James Shaen,[3] Henry Osborne, Miles Symner, Adam Molyneux, Captain William Webbe,[4] Richard Francis, and (occasionally) Anthony Morgan.

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1. 'Less sophisticated' with regard to scientific procedures implemented in the Survey, in comparison with those depicted in Solomon's House. However, the complexity of the practical problems which faced Petty, and the axiomatic clarity of his organisational solutions, were in no way unsophisticated.
2. Webster, Instauration, pp.438-40.
3. For Taylor, Petty and Shaen, cf. Fitzmaurice, Life, pp.48-49; Petty became an expert surveyor and cartographer and was appointed deputy surveyor General after the Restoration. See Strauss, Sir William Petty, op.cit. p.123, and B.H. MSS. Volume 6, Section 1, item 17, letter William to John Petty, 22 January, 1660, and ibid, 25, letter 19 March, 1660.
4. For Webbe, see Barnard, Commonwealth Ireland, p.227.

Petty also utilised the expertise of Henry Sutton, a London instrument maker[1] reknowned for his accuracy and, possibly, the devoted services of Samuel Knibb.[2] An associate of Sutton's, Knibb may have been the mysterious 'Sam', whose honesty and support Petty acknowledged when writing to Hartlib during these years. There can be no doubt that without this reservoir of talent, Petty's task would have been insurmountable.[3] His role, therefore, was to integrate the work of these assistants along lines exactly comparable with Bacon's dictum in De Augmentis.[4] Petty was the director of the whole operation, the 'interpreter of Nature', devising logistical procedures which were an integral part of the 'New Organon'. He himself argued that this was his primary role:

> 'I was never surveyor by office, but undertaker by contract, and rather a contriver of the way and method how many surveyors should worke, then a surveyor myselfe, having never given any particular directions aforehand, nor made any alteration of their worke afterwards'. 5

The next stage of the 'technical' hierarchy was constituted by a small number of senior assistants, who accepted Petty's 'order and method', and themselves trained, or 'led the hand[s]' of the multitude of less skilled workers. From the ranks of this elite were recruited experts capable of tackling one of the most difficult tasks:

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1. For Sutton see Taylor, Mathematical Practitioners, op.cit. p.220; Petty, History of ... Down Survey, op.cit., p.324.
2. For Knibb, see Taylor, op.cit., p.251. Letters referring to 'our friend Sam' at Yale University, Osborn MSS. 63/4, are dated, 23 October, 1652; 28 June, 1654; and n.d., but c.1658. 'Sam' was a trusted business agent of Petty's, especially in his protracted and tortuous relations with Brasenose College.
3. There were other anonymous men whose skills Petty utilised. Thus, Hartlib noted in his M.S.Ephemerides, 1655, 36-36/6, when discussing Petty's surveying work 'His man Tom is wonderfully inventive handy and mechanical and a mighty help unto him'.
4. See above, p. 127.
5. Petty, History of Down Survey, op.cit. p.294.

> 'Over and above all these, a few of the most nasute and sagacious persons, such as were well skilled in all the partes, practices, and frauds appertayninge unto this, or whereunto it was obnoxious, did in the first place view the measurers ffeild bookes, and there by the same critickes as artistes discerne originalls from copyes in paintinge ... did endeavour to discover any falsification that might be prejudiciall to the service. The same men alsoe reprotracted the protractions ... , compared the comon lines of severall men's worke, examined wheather any of the grounds given in charge were to be omitted; and, lastly, did cast up all and every the measurers workes into linary contents ...' 1

Finally, the central administrative office employed a team of men who were:

> '... instructed in the art of protractinge, that is, in drawinge a modell or plott of the lands admeasured, accordingle to a scale of 40 perches to the inche, according to the length and bearinge of every side transmitted unto the said protractors in the ffield bookes of the measurers ... the which protractions were made uppon the papers aforementioned, which were squared out into areas, some of 10, some of single acres. These men, and sometimes others of smaller abilities, were employed to count how many of the said greater or lesser intire areas were comprehended within every surround'. 2

By using a decimal system, and squared paper for calculating and equalising the area of different parcels of land, the tricky problem of reducing measured and protracted materials to a uniform size was itself diminished. This was absolutely necessary, since the unusually large maps produced by the initial process of 'laying down' had to be standardised, and presented to the commissioners in bound volumes. These books contained maps of the 'barrony plotts', which accurately expressed their different acreage, and, at the same time, were in a form which facilitated

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1. Ibid, pp.xvi-xvii.
2. Ibid, p.xvi.

ready reference and handling. Further reference volumes, 'written fair' by some of Petty's forty clerks, accompanied these maps, enabling the commissioners to correlate ownership with the extent and quality of individual territorial units.

In Petty's own estimation the most important operational level was located at the base of the organisational pyramid: the field work, or 'ministery of about one thousand hands'. Only the army's willingness to provide a substantial body of men allowed Petty to tackle the immense challenge of the Survey so quickly and efficiently. This was the fulcrum around which the entire project moved:

> 'But the principall division of this whole worke was to enable certayne persons, such as were able to endure travaile, ill lodginge and dyett, as alsoe heates and colds, beinge alsoe men of activitie, that could leape hedge and ditch, and could alsoe ruffle with the severall rude persons in the country, from whome they might expect to be often crossed and opposed. (The which qualifications happened to be found among severall of the ordinary shouldiers, many of whom, havinge bin bread to trades, could write and read sufficiently for the purposes intended). Such, therefore (if they were but headfull and steddy minded, though not of the nimblest witts) were taught, ... how to make use of their instruments, in order to take the bearinge of any line, and alsoe how to handle the chaines, especially in the case of risinge or fallinge grounds; as alsoe how to make severall markes with a spade, whereby to distinguish the various breakings and abutments which they were to take notice of; and to choose the most convenient stations or place for observations, as well in order to dispach as certaynty. And lastly, they were instructed, per autopsiam, how to judge of the vallues of lands, in reference to its beare qualities, and accordinge to the rules and opinions then currant, to distinguish the profitable from such as was to be thrown in over and above, and not paid for at all'. 1

The equipment and field books provided for these men were adapted by Petty and his staff from existing models. As long as the teams

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1. Ibid, pp.xv-xvi.

working in the field kept their records and maps in meticulous order, it was possible for them to utilise the circumferentor and chain. These instruments, easier to use than professional theodolites and plane-tables, were sturdy, cheap, and easy to manufacture. Petty probably utilised the improved decimal chain advocated by Gunter, and adapted the circumferentor described by Rathborne, simplifying it even further[1] with Henry Sutton's help. Whatever the exact nature of these instruments, they proved to be highly effective in the field, and, when combined with Petty's 'more distinct, methodicall, and comprehensive ffield booke',[2] and Henry Sutton's squared paper,[3] produced maps with a degree of error of only ten[4] to fifteen per cent.

The instruments themselves were mainly produced by the army, using a system of specialised production which Petty had probably seen operating in London's manufactories. Thus a wire maker produced the measuring chains, a watch maker the magnetic needles, a founder specialised in brass work, and 'another workman, of a more versitile head and hand, touches the needles, adjusts the sights and cards, and adaptates every piece to each other'. Other materials like 'royall-paper ... colours, pencills', and instruments such as 'tyme-scales, protractors and compasse-cards'[5] were made by specialists in London.

At all levels and stages of the enterprise, Petty worked with enormous energy, insight and ingenuity. Although resting on the shoulders of others, his was the mind which conceived, co-ordinated and directed this massive and successful project. Of equal importance,

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1. Webster, Instauration, pp.439-40; Petty, History of ... Down Survey, p.17.
2. Ibid, p.17.
3. Ibid, pp.XV, 324. For Sutton, cf. Bodleian Lib., Rawlinson. MS. A. 208. f.457 'Paid ... December 1653 for mathematicall instruments for ye service of ye publique in Ireland ... Henry Sutton £20:2:00.'
4. Strauss, Sir William Petty, p.71. Andrews, Introduction to Hiberniae Delineatio, op.cit. p.3. Y.M.Goblet, A Topographical Index of the Parishes and Townlands of Ireland, in Sir William Petty's MSS. Barony Maps. (c.1655-9), (Dublin, 1932), p.vi.
5. Petty, History of ... Down Survey, pp.xiv-xv.

however, was the internal effect on Petty's own attitudes. These changes, and his relationship with the broader movement for geographical natural histories necessarily require a brief analysis.

Petty's understanding of the Survey's value was undoubtedly an extension of Baconian and reformist ideas, and of his own early experience. Hartlib's appreciation of the Survey's true potential grew as the project developed, and as fresh reports filtered back from Ireland. Whereas in May 1654,[1] he noted a decline in his reputation in London, in the following months Petty's work on dialling attracted warm praise.[2] A few years later, following occasional comments on geographical natural history, and Irish cartographic projects,[3] Hartlib received a glowing report from Robert Wood. Having discussed Symner's work on the 'Irish Interrogatory', Wood said:

> '... we expect accurate Mapps of Ireland from Dr Pettye's Surveyes, those of Speed, all others taken out of them being extremely defective in many particulars and grossly faulty, the country considered impartially is in itselfe a brave country, beyond what the English generally will ever be persuaded to imagine & wants nothing but an industrious people'. 4

It is clear, therefore, that Wood, Hartlib, Symner, and probably Petty himself, regarded the Survey as an adjunct to the general programme for Irish natural history. Yet Petty's work, in both the mode of expression, and in the method used to collect the data, was fundamentally different to that exemplified in the 'Interrogatories'. Although the Survey was a mathematical, or geometrical expression of similar information, its success depended entirely on the method, comprehensiveness

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1. Boyle, Works, (1772 ed), vi, 88, letter Hartlib-Boyle, 8 May, 1654.
2. See above, p. 116 n. 2.
3. See Hartlib Papers, M.S. Ephemerides, 1656, 37-37/8, and 1657, 49-49/7.
4. Hartlib Papers, xxxiii/1/ f.15v, Wood to Hartlib, 27 May, 1657.

and accuracy of this mathematical work. Again, Petty's geometrical and statistical interpretation of economic, topographical and social data, was the Baconian counterpart of Hobbes' geometrisation of 'Optiques' and 'naturall justice'. Yet Petty's method was, perforce, different to that of Hobbes, in that, with regard to social phenomena, his 'ratiocination' was (optimally) based on empirical, as opposed to a priori, grounds.[1] Led by the dictates of the Survey, Petty came to realise that scientific axioms about natural social laws could only be based on extensive empirical research, and expressed in mathematical terminology. This was what set his understanding apart from that of Boate, Child, Hartlib, Worsley, Hobbes and even Bacon. Only Petty had the experiential and intellectual training which allowed him to make this essential synthesis. Admittedly tautological, the argument that Petty alone was capable of developing the concept of 'Political Arithmetic', because it was he who subsequently produced tangible results in the field, also has some validity.

That the Survey did have the described effect, and was also a synthesis of English and continental attitudes, was confirmed by Petty in 1660. Although his Reflections upon ... Ireland was a polemical work aimed at enemies like Sankey and Worsley, he still prefaced its propagandist material with more generall, methodological pronouncements. Reading between the lines, and taking into account immediate circumstance and his avowed reticence over this subject, Petty's statements confirm the interpretation outlined above. He apologised for leaving the 'Study of Medicine', with 'those other Mathematical, Mechanical and

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1. Thus, compare Petty's approach in the Survey, and his subsequent economic views (Chapters 2 and 4 below) with the brief summary in, A.Levy, 'Note: Economic Views of Thomas Hobbes', J.Hist. Ideas, 15 (1954), 589-595, especially 589.

Natural Exercises' in 1654, and for diverting his attention to the traumas of the Survey. His excuse for this behaviour was:

> '1) I thought the whole work wou'd have been over ... in about two years times; so as to have proved rather an unbending than a breaking of that Bow, wherewith I aimed at natural Knowledges.
> 2) I thought that the measuring of as much Landline by the Chain and Needle, as would have neer four times begirt the whole Earth in its greatest Circle, and to have such an Admeasurement remain upon Record, and that to have performed such a Service (being useful to all Mankinde) for a Victorious Army ... would have been as great an Honour as any other Atchievement I could make in so much time; .....
> 4) I thought by attempting new difficulties to have stretcht my own capacity and intellect, the which ... is not only formed and fashioned, but much extended by such Employments.
> 5) I hoped hereby to enlarge my Trade of Experiments from Bodies to Mindes, from the motions of the one, to the manners of the other, thereby to have understood passions as well as fermentations, and consequently to have been as pleasant a Companion to my ingenious friends, as if such intermission from Physicks had never been:' 1

Technology, utility, the extension of his scientific interest to encompass practical problems when linked with mathematically-oriented, socio-economic research (and the idiosyncratic nature of the quotation itself) help place the preceding analysis in its correct perspective.

The Down Survey, as much as Boyle's famous work on gases,[2] Hooke's mechanical inventiveness,[3] or Grew's innovative botanical histories,[4] was thus a triumphant, specialised example of English Baconian science.

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1. Petty, Reflections upon ... Ireland, op.cit, pp.12-15.
2. See D.Krook, 'Two Baconians: Boyle and Glanvill' Huntington Library Quarterly, 18 (1954-1955), 261-278, especially 267-274; I.B.Cohen 'Newton, Hooke and "Boyle's Law"' Nature, 204 (1964), 618; C.Webster 'Richard Towneley and Boyle's Law' Nature, 197 (1963), 226-228; R.E.W.Maddison, The Life of ... Robert Boyle (London, 1969), pp.224-6.
3. For Hooke as Baconian see F.F.Centore, Robert Hooke's Contributions to Mechanics, A Study in Seventeenth Century Natural Philosophy, (The Hague, 1970), pp.14-40. E.N. da. C.Andrade, 'Robert Hooke' Proc. Roy. Soc. A., 201 (1950), 439-473.
4. For Grew's natural history of plants see, J.Bolam, 'The Botanical Works of Nehemiah Grew, F.R.S. (1641-1712)', Notes Recs. Roy. Soc., 27 (1973), 219-231, and N.Grew, The Anatomy of Plants with an Idea of a Philosophi-

Although unique in its organisational and operational details, it was inspired by the common philosophical apparatus of Bacon, and made concrete through the dynamic abilities of a leading English practitioner. In reverse, the Survey encouraged the translation of this natural philosopher from his role as doctor, technologist, and improver, to that of the empirical political-economist, proceeding on mathematico-deductive lines. Supported by his subsequent governmental experience, the Survey acted as a catalyst, whereby elements derived from Petty's early training were fused with mathematical methods (hitherto present but under-utilised), creating the powerful techniques of Political Anatomy, Political Arithmetic and Political Algebra.

Before leaving this period of Petty's life, brief attention must be paid to his relations with Ireland's 'visible church of Philosophers' and their counterparts in England. Any description of Irish natural philosophy, and of Petty's role in its development from 1652 until his death, must be placed against a backdrop of two prominent features. To begin with Ireland was intellectually underdeveloped: the problems facing natural philosophers, substantial enough in England, were in Ireland almost overwhelming, especially during the Interregnum. Secondly, in a personal sense, Ireland made exhausting demands on Petty's intellectual energy which repeatedly interrupted his pursuit of these more esoteric interests.

The detailed development of Ireland's nascent scientific movement is currently exciting vigorous debate.[1] Whether any single interpre-

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1. See Barnard, Commonwealth Ireland, pp.213-226, 229-248, especially 244-248. 'The historian of the Dublin Philosophical Society, following William Molyneux, has tended to play down the earlier activities, suggesting that the Society's foundation initiated something new. I believe that the Society is more convincingly seen as the culmination of an interest in the new Science which had been growing steadily in Ireland, at least since the 1630's and which received a great fillip in the 1650's', ibid, p.246. See also idem, 'The Hartlib Circle and the Origins of the Dublin Philosophical Society' op.cit.; K.T.Hoppen, The Common Scientist, op.cit. and idem 'The Royal Society and Ireland: William Molyneux, F.R.S. (1656-1698)' Notes Recs. Roy. Soc., 18 (1963) 125-135, especially 125.

tation is correct, or whether the truth will prove to be an amalgam of several, has not yet been established. It is clear, however, that a small number of Ireland's natural philosophers maintained a fragile and intermittent relationship, in an environment with few amenities (technical or institutional), even fewer centres facilitating coherent activity, and many powerful distractions. In 1654 Boyle maintained:

> 'I live here in a barbarous country, where chemical spirits are so misunderstood, and chemical instruments so unprocurable, that it is hard to have any hermetic thoughts in it, and impossible to bring them to experiment'. 1

Petty echoed this attitude, also referring to Ireland as 'this Barbarous country',[2] and decried the lack of educational and technological progress. Several years later Robert Wood complained of a paucity of printed material: 'there is scarce anything to be had at our stationers that savours of Ingenuity'.[3] The response of Hartlib to such complaints was to chide those who grumbled, and exhort them to greater co-operative efforts. His reply to Boyle typifies this advice:

> 'Sir, you complain of that barbarous (for the present) country wherein you live; but if you would but make right use of yourself, from the place where you live, towards Dr. Child, Mr. Worsley, Dr. Petty, Major Morgan (not to mention others) they would abundantly cherish in you many philosophical thoughts ... [and] divers choice chemical experiments...' 4

Yet a great deal stood in the way of such co-operation. For example,

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1. Boyle, Works, (1722 ed.), vi, letter to Clodius, undated but c. January 1654.
2. Yale, Osborn MSS. 63/4, letter to Hartlib, dated 1/9 March 1653.
3. Hartlib Papers, xxxiii, 1, f.9.
4. Boyle, Works, (1772 ed.), vi, 81, letter Hartlib-Boyle, 28 February, 1654. Boyle's complaint was passed to Hartlib by his son-in-law, Clodius.

Robert Child, one of the suggested collaborators, died (unbeknown to Hartlib) before this letter was written.[1] Again, Boyle's residence outside Dublin limited easy intercourse with such associates, as Petty's letter a year earlier bore out:

> 'Now, indeed, I am forced to communicate with you, even to keep up the face of the visible church of philosophers; for, by MR. Worsley's going to England, and major Morgan's absence in the North, there is no such thing now left at the head thereof ...' 2

Indeed it is arguable that the 'church of philosophers' was only 'visible' because of its tiny membership and arcane interests. It was an insubstantial fellowship, for the reason that its members were so often absent on government business, or so hard-pressed by these affairs, that they had little time for joint scientific endeavour. Petty was an extreme example of this situation. In 1657, when asked by Hartlib to answer a 'dialling' puzzle, he wrote:

> '... [this] seemes to bee a little Challenge to mee for triall of my sufficiencies etc. You know my head is at this tyme, but in an ill condicon to solve Such problemes as are beyond the Propounder's Mathematicks ...' 3

The pressures of government bore heavily on the new Secretary to the Council, replacing the equally oppressive demands of the Survey.[4] Symner, Morgan, Worsley and Wood all experienced similar incursions on their time.

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1. Cf. Petty's letter to Hartlib, dated 19 February, 1654, at Yale, Osborn MSS. 63/4.
2. Boyle, Works, (1772 ed.), vi, 138, letter dated 13 April, 1653.
3. Yale, Osborn MSS. 63/4, letter dated 22 September, 1657.
4. Petty wrote to Hartlib several times, between 1653 and 1658, bemoaning the lack of time for abstract, experimental research. For example, see the letter dated 11 November, 1657, at Yale Osborn MSS, 63/4, ' ... I will [soon] have another bout, at learning; as shall both strayne my ability & demonstrate my willingness to advance it. In w^{ch} persuasion I desire you & my freinds to remaine, for What I have beene doing here is but to prepare mee thereunto'.

When co-operative activity occurred, it was usually the product of two individuals. As we have seen, Petty worked with Morgan on dialling in 1653. Wood consulted Symner over Irish natural history, and kept up a close association with Petty from his arrival in 1656 until his death in 1685.[1] Even Boyle, while disliking Ireland and returning to England as soon as possible,[2] managed to indulge in some limited research:

> 'For my part, that I may not live wholly useless, or altogether a stranger in the study of nature, since I want glasses and furnaces to make a chemical analysis of inanimate bodies, I am exercising myself in making anatomical dissections of living animals: wherein (being assisted by your father-in-law's ingenious friend Dr Petty, our general's physician) I have satisfied myself of the circulation of the blood, and the (freshly discovered and hardly discoverable) receptaculum chyli, made by the confluence of the venae lacteae; and have seen (especially in the dissections of fishes) more of the variety and contrivance of nature, and the majesty and wisdom of her author, than all the books I ever read in my life could give me convincing notions of.' [3]

Contact with Petty may have led Boyle to consider Oxford as a location for future scientific work, and to the ensuing period of brilliant collaboration with Hooke. Nonetheless, such co-operative endeavour produced few tangible results, and was easily terminated by personal animus or Ireland's multiple distractions. Despite his efforts, Hartlib was unable to orchestrate the activities of his Irish colleagues, owing to a host of insurmountable problems. Distance, and inefficient communications were alone sufficient to disrupt these attempts. Beyond

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1. See Wood's letters to Hartlib, at Hartlib Papers, xxxiii, for the period 1656-1661. Many incidental references are made to these friendships, especially at f.3v, (10 June, 1656), f.13.v. (8 April, 1657), and f.23.r (1 August, 1657).
2. For this aspect of Boyle's Irish experience see, R.E.W.Maddison, 'Studies in the Life of Robert Boyle, F.R.S. Part VI. The Stalbridge Period, 1645-1655, and the Invisible College' Notes Recs. Roy. Soc., 18 (1963), 116-119.
3. Boyle, Works, (1772 ed.) vi, 55, letter to Clodius c. January, 1654.

that, as political events rushed ahead, men like Worsley and Petty came into conflict, and as the reform movement's influence began to wane, the tenuous links between these few like-minded men in Dublin came under increasing strain. 'The visible church of philosophers' therefore possessed a highly restricted, oft-fragmented congregation.

A classic example, embodying all these elements, is provided by Petty's deliberate obstruction of the plan to provide Hartlib with a steady income, and create in Dublin an international correspondency for the advancement of learning.[1] Initiated by Eccleston and Rand in 1655, the project aimed at purchasing military scrips and debentures, and offsetting these against forfeited property in Ireland to provide funds and a location for the agency. Worsley was given the task of organising the Irish end of the business. His close alliance with Sankey (Petty's old enemy) and other extreme sectarians, alerted his opponent and alarmed Henry Cromwell. Petty, with Cromwell's support, delayed the passage of necessary documents through the Council, and did everything he could to obstruct the plan.[2] Despite written pleas from Boyle[3] and Hartlib, and subsequent conversations with both,[4] he was unrepentant, and even tried to divert the money to his own project for a 'college or colony of twenty able learned men, very good Latinists, of several nations, [to] teach Latin ... by use and custom. This, with the history of Trades, he looks upon as the great pillars of reformation of the world.'[5]

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1. Accounts of this are given in Webster, Instauration, pp.74-7, and Barnard, Commonwealth Ireland, pp.229-233.
2. This is described in Hartlib Papers, xlvii, 3, ff.1-4 'Extracts of Letters concerning the busines of Learning. Dublin, Jan: 27, 1658'. Digests of Worsley's letters between January, and July 1658.
3. See Petty's reply to Boyle's letter at Boyle, Works, (1772 ed.), vi, 139-140, letter dated 17 February, 1658.
4. Clodius also tried to persuade Petty, cf. ibid, 110.
5. Ibid, 113.

Petty's reasons for obstruction were mixed. Jealousy and suspicion of Worsley, fear of the agency's potential influence, lack of communication with English reformers,[1] anger at suspected plagiarism of his early ideas, and many broader considerations, helped reinforce his obstinacy. When combined with his powerful position in the Irish administration, and his influence over Cromwell, these factors gave Petty the power and the will to destroy a viable and constructive plan.[2] By 1659 Hartlib had become justifiably disenchanted with many of his former proteges. Petty's motives, previously suspect, were now confirmed as malign and selfish in the eyes of Hartlib and Boyle. Robert Wood, who remained aloof over this dispute, was criticised for his lack of ardour: 'Really, I had expected a more generous answer from MR Wood'.[3] Even Worsley, struggling for survival in the murky waters of pre-Restoration politics, drew back from his relationship with Hartlib, and was castigated accordingly:

> 'I shall endeavour to inform myself the best I can, concerning the way of making Salt petre out of sea salt. I wonder that MR Worsley, that was one so hot upon this subject, both for writing and acting, hath been so much cooled in both respects. I wonder also not a little at his perverse and obstinate silence.' [4]

The fellowship of natural philosophers in Ireland, faulted for so long, fell rapidly apart as chaos loomed at the end of the Interregnum. Whereas the Restoration confirmed the English movement for establishing a formal scientific organisation, it provided a disincentive for natural philosophy in Ireland. Partly because many intellectuals were drawn back to London to protect their interests, partly because of Ireland's back-

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1. In letter to Boyle, 17 February, 1658, ibid, 140.
2. See Worsley's letter (copy) to Hartlib, dated 14 July, 1658, at Hartlib Papers, xlvii, 3, f.4.r. + v.
3. Boyle, Works, (1772 ed.), vi, 111.
4. Ibid, 116, letter Hartlib to Boyle, dated 5 April, 1659.

wardness and plodding orthodoxy, and partly because Dublin's scientific community was so fragile, an efflorescence in Irish science failed to materialise immediately after the Restoration. Instead, it took nearly a quarter century before the slow stabilisation[1] and growth of interest provided the tradition and basis for Dublin's Philosophical Society.

For Petty, the years between 1658 and 1660 were traumatic and uncertain. After the death of his father Henry Cromwell proved incapable of protecting his close associates,[2] who were soon hounded by extremists. Petty was no exception, being forced to go to England to defend himself in Parliament against accusations by Sankey.[3] He derived great compensation during this time of strain from the renewal of his old association with natural philosophers in England. Although an infrequent correspondent, Petty had not entirely neglected to communicate with erstwhile colleagues. Thus, Wren's fulsome letter early in 1658, sent via their mutual friend Robert Wood (who had returned to England the previous July),[4] outlined recent scientific developments in Oxford, and thanked Petty for his kind remembrance:

> 'Hon'd.Sr. It's much above my desert that you have been pleas'd to let me be frequently sensible, as you have had occasion to write to Wadham College, that you allow me a room in yr. memory: ... and now especially you extremly

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1. See T.C.Barnard, 'Miles Symner and the New Learning in seventeenth century Ireland' op.cit., 136-137 for a similar statement, and K.T.Hoppen, The Common Scientist, op.cit, p.23., on Dublin's development in the 1680's.
2. See Cromwell's sympathetic letter to Thurloe on Petty's behalf, at J.Ward, Lives of Professors of Gresham College, op.cit., p.220, dated June 1659, and to Fleetwood, at Fitzmaurice, Life, pp.87-88, also June 1659.
3. See Hartlib Papers, 1v, 12, f.1.r, for a copy of Sankey's charges, as laid before parliament on 24 March, 1659. Petty replied to these in his Reflections upon Ireland, op.cit., See also L.Sharp, 'The Royal College of Physicians ...' op.cit., 124-126, and n.99, for the extremists' use of Petty, as a stalking horse for Henry Cromwell.
4. For Wood's arrival in Ireland c.May 1656 see Hartlib Papers, xxxiii, 1, ff.1-2; for his departure to England in July, 1657, ibid, f.21.r; for his return to Ireland in April 1658, Hartlib Papers, xv, 4, f.3r.

> highten the Obligation, if you suffer me to have any lodgement in yr. thoughts, when sacred Business fills you, when you sit at the Helme and Steer a Kingdom'. 1

Petty visited England on urgent business several times during 1658 and 1659, remaining in London from the summer of 1659 until the political crisis passed.[2] Once again, he joined circles of *avant garde* intellectuals. He frequented Harrington's discussion club at Miles Coffee House in Old Palace Yard,[3] debating the constitutional options with an astringent but experienced air ...'[he] was a Rota-man & troubled MR Ja: Harrington with his Arithmeticall proportions, reducing Politie to Numbers'.[4] However, the uncertainties of the situation were such that Petty awaited the outcome of events with trepidation. Although he eventually kept his possessions and lands, he lost his government posts, his fellowship at Brasenose, and the Chair of Music at Gresham College, which he had neglected since leaving for Ireland. It was impossible for him to forecast what might happen, and, when the

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1. Transcript of Wren's undated letter to?, but probably Petty, at J.A.Bennett, 'A Study of Parentalia with two Unpublished Letters of Sir Christopher Wren' *Ann. Sci.*, 30 (1973), 146-147. Bennett dates the letter as 1656, but, since Petty did not become Secretary to the Council until long after Wood's arrival in May 1656, it is more likely that Wren wrote the letter during Wood's visit to Oxford, in August 1657, and that Wood, delayed by unforeseen circumstances, finally posted the letter to Ireland at the end of the year. This chronology agrees with Petty's unmistakeable reference to the letter's news, in a missive sent to Boyle, dated 17 February, 1658 [N.S.], at Boyle, *Works*, (1772 ed.), 139-140. Further internal evidence from this letter, relating to Hartlib's correspondence over Petty's obstruction of the Dublin agency, confirms this conclusion.
2. See letters in B.M. MSS.6, section 1, from William to John Petty in Dublin, which establish that he was domiciled in London from mid-1659 to autumn 1662.
3. For this club cf. *The Diary of Samuel Pepys*, ed. R.Latham and W. Mathews (London, 1970-) i, 13 (n.3), 14 (n.3), 17(n.2), 20, 21 (n.1); henceforward 'Pepys, *Diary*...' Aubrey, *Brief Lives*, i, 288-295, *Lives ... of Professors of Gresham*, *op.cit.*, p.221.
4. Keynes, *Bibliography*, p.91. (Aubrey's account of Petty).

Restoration finally resolved the political chaos, he entered a new cultural and social world that, paradoxically, praised his achievements, only to reject them, denying him an opportunity to test those new concepts fostered by the Survey's hard but fruitful training.

(g) Frustration and Achievement, 1660-1687.

The later years of Petty's life have received much more extensive, well-informed historical and biographical treatment than the early period between 1623 and 1660. In particular, Strauss has given a succinct and imaginative portrait of Petty's activities, as businessman, litigant,would-be politician and government official, author, and colourful personality.[1] Nonetheless, large gaps still exist in this biographical picture, especially over his relationship with the personalities and institutions of post-Restoration natural philosophy, and his role as a brilliant, but unheeded social analyst. The last chronological section of this intellectual biography will therefore concentrate on these lacunae, utilising and, where necessary, correcting, the well-established picture of Petty's later career.

After 1660 there were several factors which governed the nature and pattern of his interests and pursuits. The first was geographical. Petty was endowed with vast Irish estates through extensive property speculation at the end of the Interregnum,[2] and this naturally required him to pay a great deal of attention to his Hibernian possessions. Therefore, out of these twenty-seven years, only eleven or twelve were

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1. Strauss, Sir William Petty, chapters 8,10-14; this analysis of Petty's later years has more clarity and elegance than Fitzmaurice, Life, pp. 102-315, and benefited from Lansdowne's excellent publication of Bowood House manuscripts in the 1930's. See also Hull, Economic Writings, i, xxi-xxxiii.
2. Aubrey said of Petty's Irish land holdings: 'He hath yet there 7 or 8000 li. p. ann. and can from the Mount Mangorton in the com. of Kerry behold 50,000 Acres of his owne Land. He hath an Estate in every Province of Ireland', cf. Keynes, Bibliography, p.87. See also Strauss, Sir William Petty, pp.98-108.

spent in England. The others were taken up with travelling between the two countries and around Ireland itself, or by residence in Dublin, close to the seat of government. Often, as in 1673 and 1676, Petty's business affairs disrupted the established pattern of his life, requiring him to hurry from one capital to another. He therefore lived a geographically and socially fragmented existence, moving erratically between Dublin, Kerry and London.[1]

An additional problem resulted from the endless and exhausting law-suits which accompanied Petty's land ownership after the Restoration.[2] He was an intemperate and obsessive litigant, pursuing each case with an intense, even irrational determination. Furthermore, the complex and geographically disparate nature of his holdings added enormously to the liabilities of legal defence. These elements combined to produce distractions which wasted an inordinate amount of Petty's time and energy. His close friend, Sir Robert Southwell, repeatedly criticised this failing:

> '... you may imagin whether it be not a grief to me to see you involv'd in the Anguish and depradations of the Law, begining the sute with one Complaint and ending it with Twenty; running in consequence the Hazard of your Life, or the ruin of your Wife and Chilldren by the life of others. Nor can I [but] forsee a period of such like Calamites till you resolve absolutely upon other measures than what you have taken for if "Right be Immortal", and can never die, yet you have not a corporation of lives to assert it in all that variety of Channells and Courses wherein it runs' 3

Further demands were placed on Petty by unrelenting pressure for the

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1. His principal periods of residence in London were: 1660-1662, 1664-1666, 1673-1676, 1679-1680, 1682-1683, 1685-1687. Data obtained from: B.H. MSS. Volumes 5, 6, 7, 9-10, 13-19, and Birch, History, passim. When in Ireland, Petty visited Kerry at least once, if not twice a year.
2. See Strauss, Sir William Petty, pp.93-105; Lansdowne, Glanerought, and the Petty-Fitzmaurices, (Oxford, 1937).
3. Lansdowne, P.S.C, pp.34-35, Southwell to Petty, 15 September, 1677; for similar comments cf. ibid, p.55, same to same, 30 March, 1678.

effective administration of his estates. The worst problem was presented by the extensive properties in County Kerry,[1] whose improvement was designed as an example of Petty's plans for the general development of Ireland. These estates combined all of the most intransigent problems. Subject to extreme isolation, poor communications, natural disasters of weather and tide, depredations by neighbours and Tories, uncontrolled economic fluctuations, technical failures and legal threats to his ownership, the holdings in Kerry exhausted and drained Petty's astounding intellectual and physical stamina. Above all, the dishonesty or incompetence of his agents compounded these other factors, forcing him to make the long and hazardous journey from Dublin to Killowen on innumerable occasions. When away from Kerry he was frequently required to write extended letters to his agents, laying out his policy and demanding, or pleading for compliance.[2] Often he was close to a profound and absolute despair over these estates:

> 'O Lord when will these sorrows have an End ... As for Rents, Trade etc If they will not maintain themselves lett all fall, I will never more send from other places into Kerry - They shall not make me poor and a slave instead of (as they falsely promised) makeing me a plentifull return of my labour, Care and pences ...' 3

Such sentiments were echoed by his friends, who were disturbed by the obvious waste of an outstanding intellect on such trivia. As Southwell commented to Pepys:

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1. See Lansdowne Glanerought, op.cit., pp.1-46; H.Wood 'Sir William Petty and his Kerry Estate' J.Roy. Soc. Antiq. Irel., 64 (1934), 22-40; G.H.Orpen, The Orpen family (printed for private circulation, 1930) pp.52-82; Keynes, Bibliography, pp.45-46.
2. B.H. MSS. Volumes 13-19 contain this extensive correspondence between Petty and his Irish agents. Further material is in Osler Library, McGill University, Osler MS. 7612. See Bibliotheca Osleriana, op.cit., p.683.
3. B.H. MSS. Volume 19, pp.129-130.

> 'But for the mountaines of Kirry I wish they were leveled, yt soe the rest of the world might be the better by the repose of this Great Genius. 'Tis the Vulture that only knaws at him, and he cannot rest under his apprehension, and truly it were high-time it had an End ...' 1

To these debilitating pressures were added the interminable politicking and manoeuvring which attend a corrupt system of government and a tortuous courtly life. After 1660 Petty lost all his important governmental posts.[2] For a man with an intensely active disposition, and great experience in the control of State affairs, this caused bitter frustration and disappointment.[3] At first, Petty intended to avoid public and political life:

> 'I shall not much trouble myselfe about employments at present, I verily believe that a yeare or two of privacy will doe better for us all; I served under [a] Monarchy as I thought settled, I will serve no more untill a better Monarchy bee better settled ... ' 4

Yet his attitude to involvement with public events was ambivalent. In reality he craved a government post, for his whole intellectual approach demanded that he put into effect the new methods he had devised between 1652 and 1660. This Baconian impulse for concrete demonstration of theoretical axioms reinforced his own passion for active participation in economic and social matters. Consequently, a year after making the above comment, Petty complained to John Petty 'I am busy about I know not what ... And thus little by little my life will crumble away'.[5]

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1. B.H. MSS. Volume 12, letter 14, 20 September, 1684.
2. After 1656, Henry Cromwell made Petty one of the Commissioners for the distribution of lands, a Clerk to the Council, and his personal private Secretary. Petty was, however, never created Surveyor General due to obvious reasons of administrational propriety, and the enmity of opponents like Sankey and Worsley. In 1660 Petty was appointed a Commissioner for Irish Lands, under the Act of Settlement but this was a non-executive post that was soon removed. Cf. R.W.Ramsay, Henry Cromwell (London, 1933), p.358.
3. See Strauss, Sir William Petty, pp.120-134.
4. B.H. MSS. Volume 6, Section I, letter 53, William to John Petty, 17 April, 1660.
5. Ibid, letter 18.

Many factors militated against his successful attainment of office after the Restoration. At the outset he presented radical and heterodox opinions about some leading professional groups. For example, in his Treatise of Taxes he castigated the legal, medical, academic, and clerical establishments.[1] Although anonymous, this tract was soon associated with its outspoken author. When asked by Aubrey sixteen years later whether he would countenance a new edition of the work, Petty declared 'As for the Reprinting [of] the booke of Taxes, I will not meddle with it. I never had thanks for any publick good I ever did. Nor doe I owne any such booke'.[2] Petty also lacked many of the courtly sensibilities that could shield or soften this radicalism, which was accentuated by his unfortunate talent for mockery and invective.[3] Despite, or perhaps because of, the brilliant and original schemes devised by Petty, his repeated attempts to gain control of such central government functions as the collection of Irish taxes, always met with failure. As Evelyn said:

> 'He could never get to be favoured at Court; because he outwitted all the projectours that came neere him: In my life having never know[n] such a Genius, I cannot but mention these particulars, among multitude of others, which I could produce'. 4

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1. Hull, Economic Writings, i, 21-31, Chapter 2, 'Of The Causes which encrease and aggravate the several sorts of Publick Charge'. Pepys quickly knew that the book was by Petty. Cf. Diary, iii, 286, 19 December, 1662. See also Strauss, Sir William Petty, 138-145.
2. Cf. Appendix 3, vi, number 8, letter dated 29 May, 1678.
3. This dangerous ability led to imprisonment in February 1677, when he was accused of defaming the Lord Chancellor, Sir Heneage Finch. Cf. Lansdowne, P.S.C. pp.14-20; Keynes, Bibliography, pp.15-16, and ibid, Evelyn's account, p.94. Finch was well appraised of Petty's opinions, owning a copy of his Reflections upon ... Ireland, which is in the present author's private collection.
4. The Diary of John Evelyn, ed., E.S. de Beer (Oxford, 1955), iv, 60, entry 24 March, 1675.

This theme is of great significance with regard to the nature of Petty's later 'projects', and will receive more adequate attention in a subsequent chapter. For the moment, however, it is sufficient to note that Petty succeeded only in gaining government employment as Registrar to the Irish Court of Admiralty (1676).[1] Even then he resigned this minor post a few years later over a question of ethics, and flagrant abuse of the law[2] by court officials.

In retrospect it is clear why Petty's great administrational and organisational talents were not utilised by the government after 1660. Justifiable suspicion of his financial motives, jealousy of his outstanding ability, and his own unmitigated tactlessness, jointly conspired to block his path. Above all, his attitude to the role and method of government, drawn from experience in Holland and England during the Interregnum, meant that he was hopelessly out of tune with the political and social ethos of post-Restoration life. Thus Charles II, with his acute sense of the possible, noted dryly:

> 'That he thought .. [Petty] .. one of the best Commissioners of the Navy that ever was; That [he] had vast knowledge in many things - "But" sayd he "the man will not be contented to be excellent, but is Still Ayming at Impossible Things"'. 3

The rejection that Petty suffered at the hands of leading political figures in 1649 and 1650 was vigorously repeated after 1660. Never again was he able to practise those brilliant skills which had been so effectively

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1. See Brit. Mus. Lansdowne MSS. 1228, f.41, Petty's speech at his first sitting as Judge of the Admiralty, 2 April, 1676. He was also named as a member of the inoperative committee for London's pavements and sewers in 1662. Cf. The Diary of John Evelyn, ed., de Beer, op.cit., iii, 318-319, 329.
2. Fitzmaurice, Life, pp.246-250; Lansdowne, P.S.C., pp.49-50, Petty to Southwell, 19 March, 1678.
3. Lansdowne, P.S.C., p.281, letter Southwell to Petty, 13 August, 1687. Charles I's memory was at fault here. Petty was never a Commissioner of the Navy, and the King was either referring to Petty's role as registrar, or implying that he '[might have been] one of the best Commisioners...'

utilised on behalf of the Irish government during the Protectorate.

Thus, except for the final years of his life, Petty wasted a disproportionate amount of time pursuing these elusive and costly interests. Even as late as 1684 he was still obstinately and profligately involved with such activities, again with a total lack of success:

> 'Pray thank on my behalfe these friends who keep [the] Kerry business afloate, so as wee may be ready to saile if wind presents. O Cousin, wee want a wind! This rowing at oares against wind and tide breakes my heart. The best rights and reason are but oares, favour and kindnes are the Wind, and I am but a Galley Slave etc. I should scarce beare your departure from London, but that I think you may be back againe before we have on this side gott through the 4 points and Scraps.' [1]

Yet frustration in his search for employment and influence with the government produced some positive results. Had Petty succeeded in gaining an important administrative post, his attentions would have been engaged by day-to-day affairs and the practical application of his novel techniques and concepts. Just as English natural philosophy, and subsequent generations, benefited from Bacon's enforced retirement after his fall from power in 1621, so Petty's bitterly resented unemployment led him to write some of the most significant economic and sociological works of the later seventeenth century.

After the Restoration Petty passed through three phases of authorship, as far as his major works were concerned. Between 1660 and 1662 he wrote, and then published, the Treatise of Taxes, [2] and assisted John Graunt, to a lesser or greater degree, with his brilliant tract: Natural and Political Observations ... upon the Bills of Mortality. [3] His next important burst of activity took place between 1670 and 1676, though the two

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1. Ibid, p.122, Petty to Southwell, 19 April, 1684.
2. Cf. Keynes, Bibliography, pp.8-11.
3. Ibid, pp.78-82. This first appeared in 1662 under Graunt's name. For Petty's co-operation with Graunt see below, p. 363.

most impressive works of this period (which circulated in manuscript)[1] were not immediately published. During these years Petty composed Political Arithmetick and the Political Anatomy of Ireland, but they only appeared after his death in 1690 and 1691.[2] In 1674 he published his Discourse ... Concerning the use of Duplicate Proportion, which was written and printed at the behest of the Royal Society. The last stage in his career as an author occurred between 1683 and 1687, when eight separate tracts (either originals or their reprints) emerged from the press.[3] These were generally concerned with population statistics, especially global growth rates, and the comparative size of various cities, most notably Paris and London. Many of Petty's compositions, including the Treatise of Ireland,[4] only emerged from obscurity in the nineteenth and twentieth centuries, and even now a significant portion of this miscellaneous flood of later essays and schemes remains in manuscript form.[5] However, when not engaged in writing or in other political and litigious activities, Petty devoted a great deal of attention to multifarious aspects of post-Restoration natural philosophy, whether institutional, technical or personal.

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1. The Diary of Robert Hooke M.A. M.D. F.R.S. 1672-1680, ed., H.W. Robinson (London, 1968) p.380, Sunday, 10 October 1673: 'Wrote since Oct. 3d. Coppy Sir W.Petty's Improvement of Ireland. Haak. Jonathans. I gave Dr [Robert] Wood Sir W.Petty's paper, he lent me Sir W.Petty's Politicall Arithmetick ...' Wood was also responsible for the transmission of Political Anatomy in Ireland, during Petty's absence. Thus, in a letter to Petty of 28 April, 1674, at B.H. MSS. Volume 6, section 3, no.52, he wrote that he had given the Lord Lieutenant a copy of the work, section by section, much to Capel's satisfaction.
2. Keynes, Bibliography, pp.21-22, 31-36. A pirated, inaccurate and anonymous version of Political Arithmetick was printed in 1683.
3. Keynes, Bibliography, pp.17-19, 22-23, 25-28, 29-30. For the Discourse, see chapter 3 below.
4. Printed in Hull, Economic Writings, ii, 545-660, written in 1687.
5. For example, much of the material in B.H. MSS. Volumes 1 and 4, is unpublished and dates from 1682-1687.

Between 1658 and 1660 England, and especially London, was in a state of great intellectual ferment. Along with more obvious subjects in religion and politics, the progress and problems of natural philosophy excited increasingly widespread interest. Consequently, private clubs were formed and numerous informal meetings began to take place. Some of these are well known owing to their role in the emergence of the Royal Society, and through the exaggerated claims that have been made for their pre-eminence in the institutionalisation of science after the Restoration.[1] Despite these claims it is slowly becoming apparent that there was a proliferation of such groups during this period, and that they differed widely in size, structure and interests. Thus, in addition to meetings at the College of Physicians and Gresham College, there were (among others) a 'Hortulane Society' known to Evelyn,[2] a regular gathering of mathematicians (described in Thompson's letter to Pell),[3] an association between Petty, Morgan, Slingsby, and Wood,[4] and Charleton's co-operative botanical research with Pierrepoint and Evelyn.[5]

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1. Thus see C.Webster's review article 'The Origins of the Royal Society' Hist. Sci., 6 (1967), 106-128, which substantially refutes Miss Purver's view, expressed in The Royal Society, op.cit., that Sprat's account of the Society's Oxfordian origins is correct. See also, C.G. Gillispie, 'Physick and Philosophy; a Study of the Influence of the College of Physicians of London upon the foundation of the Royal Society', J.Mod.Hist., 19 (1947), 210-223; and articles by P.Rattansi, C.Hill, and A.R. and M.B.Hall on the intellectual origins of the Society, in Notes Recs. Roy. Soc., 23 (1968), 129-168.
2. Brit. Mus. Add. MSS. 15, 948, ff.69-70v. anonymous letter dated 18 November, 1659, to (?) Evelyn, in his Correspondence Book. The letters in this volume establish Evelyn's close association with Brereton, Hartlib, Clodius and Beale prior to 1660. See also Hartlib Papers M.S. Ephemerides, 1653, KK-KK.8, LL-LL.1, MM-MM.1; 1655, 25-25.5, 36-36.5; 1660, 61-61.4.
3. Brit. Mus. Sloane MSS. 4279, f.273, letter dated 22 November, 1658, mentioning Rook, Wren, Brouncker, Sir Paul Neile, Goddard, Scarburgh, and other 'Mathematicall friends' who met somewhere in Moorfields.
4. Hartlib Papers, M.S.Ephemerides, 1660, 62-62/2: 'The Triers [of Dr. Potters Baneo designe] Major Morgan, Dr. Petty, Mr. Slingsby, Mr. or Dr. Pett, Mr. Wood. These have met several times about it'.
5. L.Sharp, 'Walter Charleton's Early Life ...' op.cit., 337-340.

The patterns of group and individual relationships established in London in the late 1640s, and in Oxford in the early 1650s, coalesced and reinforced each other at the end of the Interregnum.[1] Other links, such as the joint purchase of a building in Lothbury by Petty, Graunt, and John Martin (subsequently printer to the Royal Society) may have helped cement the more cerebral associations.[2] As a result of these activities and interests, London provided a fertile environment for intellectual, and especially scientific, developments during these years. It appears to the historian as if this rich cultural atmosphere rapidly progressed towards a critical state in 1659, seemingly waiting for an event, or events, to occur which would set off a chain reaction leading to the establishment of an organised society.

In 1660 and 1661 a combination of factors provided enough energy to trigger and direct this almost inevitable development. For at least twenty years innumerable plans for an institution devoted to scientific research and instruction had been circulating among intellectuals. These early projections of Plattes, Dymock, Hartlib, Dury, Petty, Beale, Wilkins et. al. were reinforced, in 1659 and 1660, by a new spate of proposals. Notable among these are Cowley's Proposition for the Advancement of Experimental Philosophy, and Evelyn's exclusive, pseudo-monastic society for gentlemen virtuosi.[3] By 1660 the desire to institutionalise the

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1. Many similar, but more isolated associations existed in Oxford and London in earlier years, cf. ibid, 312-318; J.W.Shirley, 'The Scientific experiments of Sir Walter Ralegh, the wizard earl and the three Magi in the Tower,1603-1617' Ambix, 4 (1949), 52-66; C.Hill, Intellectual Origins, op.cit., pp.132-149. See also G.H.Turnbull, 'Samuel Hartlib's Influence on the Early History of the Royal Society' Notes Recs. Roy. Soc., 10 (1953), 101-130.
2. B.H. MSS. 40, Box K, no.4, 'Transcript of Purchase deed ...' dated 8 March, 1659.
3. See A.H.Nethercot, Abraham Cowley: The Muses' Hannibal, (Oxford, 1931), pp.78-81, 140-187; L.Sharp, op.cit. 317-318, 339-340. Cowley's proposal appeared in 1661, but was probably written a year earlier. For Evelyn's plan, see Diary and Correspondence of John Evelyn, ed., H.B.Wheatley, (London, 1879), iii, 261-266, in letter to Boyle dated 3 September, 1659. The Gresham College members probably preferred Cowley's model. Cf. note 2 p. 156 below.

confused multitude of individual scientific meetings, to give them unity, form and coherence, was a deeply-rooted motive in the mind of almost every Englishman who supported the new natural philosophy. Thus, although the structural details and social purpose of the schemes themselves varied enormously, there existed among a significant number of ascendant intellectuals a common conviction and intent. This widely held hope was translated into reality by the arrival in London of important figures just before and after the Restoration. Wilkins came from Cambridge, Petty from Ireland, Boyle from Oxford, Oldenburg returned from the continent, and Moray, a devoted courtier of Charles II, accompanied his master to England at the end of his exile.[1] By December 1660 the now famous (and historiographically well rehearsed) set of rules and procedures had been adopted at meetings which centred on the professorial group of Rooke, Wren and Goddard, at Gresham College.[2]

It would be redundant to describe yet again the details of these early years of the proto-Society, especially since the present author substantially agrees with the most recent analysis of these developments.[3] This account, at the risk of over simplification, can be said to show that an 'active nucleus' of twelve members (including Petty) sustained the infant institution for its first two and a half years.[4] Furthermore, despite the heterogeneity of religious, political and methodological attitudes evinced by members of the Society (even among this select coterie) an inner cabal of leading fellows steered it towards a role which was

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1. For Oldenburg, cf. M.B.Hall, 'Oldenburg and the Art of Scientific Communication'. Brit. J.Hist. Sci., 2 (1964-65), 277-290, especially 279-282. For Moray see The Royal Society, its Origins and Founders, ed., Sir H.Hartley (London, 1960), pp.239-250.
2. T.Birch, The History of the Royal Society of London, (London 1756-1757) i, 3. henceforward, Birch, History.
3. Webster, Instauration, pp.88-99.
4. This 'active nucleus', whose composition is derived from statistical analysis of attendance at meetings (collected from references in Birch, History, i, 1-366) consisted of Boyle, Brouncker, Charleton, Croune, Evelyn, Goddard, Moray, Oldenburg, Petty, Rooke, Wilkins and Wren.

closely identified with the aims expressed in Bacon's Instauratio Magna, and towards a structure modelled on an adaptation of Solomon's House as described in New Atlantis. Once again, Petty was a leading member of this smaller group, which included Evelyn, Boyle, Wilkins, Oldenburg, and (possibly) Goddard. As the forementioned account notes, there was an intimate relationship between these figures and the evolution of Hartlib's Agency, and a strong similarity between this scheme's final form and that of the Royal Society. These factors were officially embodied in the Society's two Charters.[1] They were then purified, defended and promulgated in the apologiae of Sprat,[2] Glanvill and Cowley. This interpretation is valuable, since it makes allowance for the scientific, political and social disparity of the original Fellows, explains their common interests, and avoids the historiographical trap of creating an explanatory hypothesis, whose mechanisms demand slavish pre-selection of evidence to avoid crass inconsistency.[3] What it does not, indeed cannot, encompass is the testing of the general thesis against those detailed relationships subsequently established with the Society by leading Fellows. That task, with regard to Petty, will be undertaken briefly in the following pages.

Throughout his life Petty maintained an unyielding belief in the potential of science to refashion society. This fundamentally serious mission was never confused in his mind with attitudes and motives which prompted gentlemen virtuosi to become interested in certain aspects of

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1. See Birch, History, i, 88-96 (15 July, 1662), and 211-230 (22 April,1663).
2. T.Sprat, History of the Royal Society, ed., J.I.Cope, H.W.Jones (first published London, 1667, this ed., reprinted London, 1966), p.59, lines 13-27, where it is noted that Cowley's proposal 'very much hasten'd' the Society's foundation. Cowley's ode 'To the Royal Society' (1667) is at ibid, Sig.B.1-B.3.
3. Most clearly exemplified in Miss Purver's work, and confused in T.K. Rabb, 'Puritanism and the Rise of Experimental Science in England', Cahiers d'histoire Mondiale, 7 (1962-3), 46-67. For an attempt at a universalist interpretation see Shapiro, 'Latitudinarianism and Science in Seventeenth Century England' Past and Present, 40 (1968), 16-41.

natural philosophy.[1] Although he mixed freely and easily with these people, sharing with them characteristics such as an over-ambitious eclecticism and (occasionally) the weakness of leaving investigations unfinished, he did not share their aesthetic preciosity, or their dilettanteism. On the contrary, if his attitudes and achievements are compared even with those of John Wilkins,[2] Robert Plot,[3] John Aubrey,[4] Samuel Pepys[5] or John Evelyn[6] (who can be regarded as figures linking the

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1. For a brief description see W.E.Houghton 'The English Virtuoso in the Seventeenth Century' J.Hist. Ideas, 3 (1942), 51-73, 190-219, especially 57, and 203-205. A classic example of the virtuoso's interests can be found in G[eorge] S[inclair] Natural Philosophy Improven by New Experiments Touching the Mercurial Weather Glass, the Hygroscope, Eclipses ... By New Experiments, Touching the Pressure of Fluids, the Diving Bell ... Together with a True Relation of an Evil Spirit, which troubled a Man's Family for many days. Lastly, There is a Large Discourse anent [sic] Coal, Coal-Sinks, Dipps, Risings ... (Edinburgh, 1683).
2. For sources on Wilkins see Isis Cumulative Bibliography, 1913-1965, (London, 1971), ii, 627, especially articles by G.McColley, and The Mathematical and Philosophical Works of the Right Rev. John Wilkins, ed., L.L.Loemker (London, 1708, re-issued with Index, 1970), henceforward 'Wilkins, Works'.
3. R.Plot, The Natural History of Oxfordshire (Oxford, 1677); idem, ... Staffordshire ... (Oxford, 1686); J.Challinor 'Dr. Plot and Staffordshire Geology' Trans. N.Staffs. Field Club [T.N.S.F.C.] 79 (1945), 29-67; J.Myers, 'Dr. Plot and Land Utilisation in Staffordshire' T.N.S.F.C., 83 (1949), 58-73; R.A.Butlin, 'Plot's Natural History of Staffordshire : An Appraisal', N.Staffs. J.Field Studies, 2 (1962), 88-95; F.R.S.Taylor, 'Alchemical Papers of Dr. Robert Plot' Ambix, 4 (1949), 67-76; R.T.Gunter, Early Science in Oxford : Vol.12, Dr. Plot and the Correspondence of the Philosophical Society of Oxford, (Oxford, 1939).
4. For Aubrey cf. M.Hunter, op.cit; A.Powell, John Aubrey and his Friends, (revised ed. London, 1963); and the imperfect, Aubrey's Natural History of Wiltshire, introduced and ed., K.G.Pointing, J.Britton, (London, 1969); J.Buchanan-Brown, 'The Books Presented to the Royal Society by John Aubrey F.R.S.' Notes Recs. Roy. Soc., 28 (1974) 187-193.
5. E.N. da C.Andrade, 'Samuel Pepys and the Royal Society' Notes Recs. Roy. Soc., 18 (1963), 82-93; M.H.Nicolson, Pepys' Diary and The New Science, (Charlottesville, Virginia, 1965); F.N.David, 'Mr. Newton, Mr. Pepys and Dyse: A [sic] Historical Note', Ann. Sci., 13 (1957), 137-147.
6. E.S. de Beer, 'John Evelyn, F.R.S. (1620-1706)' Notes Recs. Roy. Soc., 15 (1960), 231-238; L.G.Sharp, 'Timber, Science, and Economic Reform in the Seventeenth Century' Forestry, 48 (1975), 63-68, and notes 79-80.

'mere' virtuosi with serious[1] post-Restoration science) the rigour and severity of Petty's social and scientific views set him apart. Instead, he should be added to a category which would number Boyle, Newton, Grew, Barrow, Locke, Wren, Halley, Hooke, Ray, Lister and Wallis among its English members. This subject will be touched on again, but should the statement raise initial doubts, it would be instructive to compare the organisational and conceptual brilliance of the Down Survey with the antiquarian natural histories of Aubrey or Plot, and Petty's passionate, undiluted belief in the social role of science with the well-established attitudes of Evelyn and Pepys.

The relevance of this serious concern for science to Petty's view of the operation and structure of the Royal Society, is of central importance to our understanding of his relationship with that institution. The attitude embodied in his early description of a 'Gymnasium Mechanicum'[2] and a 'Nosocomium Academicum' (1648), was continued in his view of the Royal Society, from its initial stage in 1660 to his death in 1687. Throughout his life he believed that an institution devoted to furthering natural philosophy should be clearly structured, well financed (preferably by the government), and should promote developments in technological, utilitarian and educational fields. This institution would become a driving force behind the total reformation of English economic and social life, and comprehensively develop both pure and applied aspects of science in a co-operative, Baconian manner. Proof of this interpretation is provided by evidence of Petty's support for the Society from 1660 to 1665, 1673 to 1676, and 1685 to 1687. It is also reinforced by his plans

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1. See the interesting comparisons over archaeology and geology with regard to these figures in: M.C.W.Hunter, 'The Royal Society and the Origins of British archaeology' Antiquity, 45 (1971), 113-121, 187-192; C.Schneer, 'The Rise of Historical Geology in the Seventeenth Century' Isis, 45 (1954), 256-268.
2. Petty, Advice, pp. 7 and 9.

for the Dublin Philosophical Society in 1683, and for the creation of colleges and hospitals in the Advice to ... Samuel Hartlib of 1648. Leaving aside the educational aspect of his early schemes and his revitalisation of the Society between 1674 and 1675 (treated in Chapters 2 and 3), a brief outline will subsequently be given to these other periods of significant activity.

Between 1661 and 1664 the Society's public image and internal structure was increasingly organised along Baconian lines. This particular 'ideological' characteristic was not accidental, and was seen by some leading Fellows as serving several purposes. Firstly, it laid upon the Society's unorthodox and questionable activities a mantle of respectability. This propagandist concern received mangificent expression in Sprat's clear, if grandiloquent prose.[1] His History of the Royal Society argued for the benign utilitarian aims of the institution,[2] purified (but distorted) its dubious political associations, by setting its origin firmly in Royalist Oxford,[3] claimed that its major role was the realisation of Bacon's great vision,[4] and strongly emphasised the extent of its royal and aristocratic support.[5] However, this Baconian scheme had a more profound purpose than mere public relations. Despite the heterogeneity of their scientific interests and capabilities and the diversity of their

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1. Cf. introduction to Sprat, History, op.cit, especially p.xxxii.
2. Ibid, pp.109, 123.
3. Ibid, pp.53-57. Cf. Webster, 'Essay Review of ... Purver' op.cit., 110-119 on this aspect of Sprat's work, and its simple-minded Baconianism.
4. Sprat, History, pp.35-36, 90, 116-117, 156.
5. Ibid, 129-133. For Charles II's interest in natural philosophy, cf. Hartley, Royal Society, op.cit., pp.39-47. See also, J.K.Dewhurst, 'Prince Rupert as a Scientist' Brit. J.Hist. Sci., 4 (1963), 365-373.

private philosophical views,[1] many of the more active Fellows supported the Society's attempt to compile Bacon's universal natural history.[2] With regard to the organisational content it is irrelevant to argue that eight official committees, created in March 1664[3] to implement this work, failed to operate efficiently.[4] Instead it is more significant that a large number of English natural philosophers were willing to join an institution with an avowedly Baconian purpose, and to accept nominal incorporation within a system designed to turn this purpose into reality.

Therefore, despite diverse views on the philosophical and social role of science,[5] a small group of Fellows, with a strong Baconian

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1. Comparison might be made between Digby, Charleton and Hill, to indicate the great variety of 'scientific' attitudes among notable early Fellows. For Digby see R.T.Petersen, Sir Kenelm Digby. The Ornament of England, (London, 1956); B.J.Dobbs, 'Studies in the Natural Philosophy of Sir Kenelm Digby' Ambix, 18 (1971), 1-26, (part I); ibid, 20 (1973), 143-163, (part II). For Charleton up to 1660 cf. L.Sharp, 'Walter Charleton ...' op.cit. For Hill cf. A.Hill, Familiar Letters [of] Abraham Hill, Fellow and Treasurer of the Royal Society ... (London, 1767); Hartley, Royal Society, op.cit., 173-182 (with bibliography); Brit. Mus. Sloane MSS. 2905. 'A.Hill: Philosophicall Papers ...' ff.1-168.
2. Cf. W.E.Houghton, 'The History of Trades: Its Relation to Seventeenth Century Thought as seen in Bacon, Petty, Evelyn and Boyle', J.Hist. Ideas, 2 (1941), 33-60; Webster, Instauration, pp.424-5; R.F.Jones, Ancients and Moderns, op.cit., pp.164, 239, and 52-57, especially 56 'More than any other element in his philosophy Bacon's conception of natural history and its importance influenced the seventeenth century ... the most prevalent motive animating scientists in the third quarter of the century was the desire to contribute to such a history'. Cf. Bacon, Works, pp.289 (Novum Organum); 405, 409-412 (Parasceve). See also P.M.Rattansi 'The Literary Attack on Science in the late 17th and 18th Centuries' (Ph.D. Thesis, London School of Economics, 1961), pp.64-70.
3. Birch, History, i, 406-407, 30 March, 1664. For example Digby was a member of two official committees, Hill of three, Charleton of three.
4. See this conclusion in R.Lennard, 'English Agriculture under Charles II: the evidence of the Royal Society's "Enquiries"' Econ.Hist.Rev., 4 (1932), 23-45.
5. Compare Evelyn's attitude, as described by M.Denny 'The Early Program of the Royal Society and John Evelyn' Mod.Lang.Quarterly, 1 (1940), 481-497, with that of Petty outlined below.

ideology, helped create the basic format of the early Royal Society. Unfortunately, the structure that they laid over its proceedings proved to be a fragile lattice-work, that fell apart as general support for the institution declined after 1667.[1] It is also true to say that the cumbersome committees, which were set up to complete the universal natural history, soon lost their appeal for many of the more perceptive members. Instead, their enthusiasm for Baconian research was transferred to private investigation, which appeared far more effective than this patently unproductive, time-consuming system.

Partly as a response to this corporate failure, Oldenburg assumed responsibility for collating and registering material for the natural history, and began to publish information received from contributors in his Philosophical Transactions. At the same time the research interests of the individual Fellows naturally developed according to more sophisticated techniques and criteria. Therefore, this spontaneous, but delayed, public recognition of Bacon's methodological influence was transformed and enhanced as new techniques and problems flooded in to react with current institutional and intellectual trends. The more circumscribed and underdeveloped world of early English natural philosophy consequently became increasingly diverse and complex after the mid-1660s. This process was greatly assisted by the Philosophical Transactions and the Society's role as a forum and channel for information. Thus, while many of the leading English natural philosophers continued to explore subjects foreshadowed in Bacon's natural history programme, better links with continental colleagues and the internal dynamic of increasingly discrete subjects caused them to shed their intellectual puparia. Thereafter,

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1. See Chapter 3, Sections 'a' and 'b' below. This Baconianism was particularly noticeable in the first issues of the Philosophical Transactions. See Phil. Trans, i (1665-1666), 1-2, 91-92, passim.

Bacon slowly receded into the background, and eventually became a potent figurehead, whose philosophy provided stimulating directives for the more perceptive natural philosophers, but suffered debasement at the hands of less disciplined virtuosi.[1]

Evidence for this sweeping interpretation is readily supplied by reference to the work of individual natural philosophers, and the progress of the History of Trades and general natural history at the Royal Society. Christopher Wren, for example, was deeply involved with technological and utilitarian improvements, as an outstanding member of Oxford's scientific community during the 1650s.[2] Influenced by the utilitarianism of Wilkins[3] (and others) between 1648/9 and 1654, and by an enthusiastic (if occasional) correspondence with Hartlib after 1655,[4]

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1. Cf. R.C.Cochrane, 'Francis Bacon and the Rise of the Mechanical Arts in Eighteenth Century England' Ann. Sci., 12 (1956), 137-156; for a thorough study of the virtuosi, their development of travel as a 'natural history' genre, and Oldenburg's central role as co-ordinator of this movement, cf. R.L-W.Caudill 'Some Literary Evidence of the Development of English Virtuoso Interests in the Seventeenth Century, with Particular Reference to the Literature of Travel' (Oxford, D.Phil. dissertation, 1975), especially pp.41-114, 215-267.
2. See Life and Works of Sir Christopher Wren. From the Parentalia or Memoirs by his Son Christopher, ed. E.J.Enthoven (Essex House Press, Campden, Glouc., 1903) pp.22-23, 'Catalogue of Theories [etc] ... at Wadham College ...'. This reprinting is here utilised in preference to the original Parentalia (London, 1750) owing to clarity of type and an extensive index. Henceforward Wren Works. See also ibid, pp.76-78 'Catalogue [of Writings]'.
3. For his high regard for Bacon, cf. Wilkins, Works, ii, 5, 37, 109, etc. and Mathematical Magic, (London, 1648) in Works, ii, 89-97. For Wren's utilitarianism cf. Wren, Works, 22-23. It is not coincidental that Book 2 of Mathematical Magic, had the same title as Aphorism 19 of De Sapienta Veterum, viz. 'Daedalus'. Cf. Bacon Works, 842-843.
4. Cf. Wren's letter on agriculture at Hartlib Papers, xxv, 9, f.1. Sent from All Souls' College, Oxford, to Hartlib in London, dated 26 February, 1655, this was probably Wren's first direct communication with the reformer. However 'several handes' including Wilkins, Rawlinson, Pett and Wood had passed on information about Wren for a number of years. (Pett and Wood were also Fellows of All Souls). Cf. Entries on Wren, especially his double-writing, and other inventions, at Hartlib Papers, M.S.Ephemerides, 1653, LL-LL2, M.M.-M.M.1, NN-NN8; 1654, WW-WW7. Hartlib printed Wren's letter in his Reformed Commonwealth of bees ... (London, 1656). For this, cf. Bibliography of British History (1603-1714), op.cit., pp.273-274. Honey was economically significant during the seventeenth century, as a major indigenous supply of saccharifferous material. Wren's letter described the Wadham experimental beehive, which was used to study bee behaviour, and improve hive design, thus maximising production.

Wren ultimately expressed his Baconianism in a concise and persuasive letter to Brouncker (as President of the Royal Society) in (?) 1663.[1] Here he argued forcefully that the Society's members needed to prove themselves 'Benefactors to Mankind' by 'advancing 1. Knowledge 2. Profit. 3. Health; and Conveniences of Life'. Well directed experiments, not theories, were important, and these must be counterbalanced by patient collecting or 'hew[ing] solid Materials out of the History of Nature'. In particular Wren discussed a 'History of Trades', 'Chemical Experiments', 'a Meteorological History' and 'A History of Things depending upon Alteration of the Air and Seasons'. Comparison of a multitude of health-affecting factors would be related to yearly fluctuations in the mortality figures, to establish which of the variables were responsible for different types and periodicities of morbidity. This enthusiasm for natural history was drawn directly from Bacon's seminal work Parasceve,[2] though Wren's description was more elaborate than Bacon's original list.

Between 1646 and 1663 Wren was, therefore, deeply influenced by Bacon's stress on systematic natural history and technological improvement. While not diminishing the enormous breadth of his scientific sources, his advanced mathematical skill or astonishing virtuosity,[3] there can be no doubt that, as one of the leading Fellows,[4] Wren wholeheartedly supported the Society's early Baconian programme. However, his development as natural philosopher and architect (two indissoluble aspects of a single

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1. Wren, Works, pp.51-56. Letter undated but probably c.1663-1664.
2. Bacon, Works, pp.402-412. Parasceve ad historiam, naturalem et experimentalem, was published in 1620 in the same volume as Novum Organum; see also M.Hunter, Aubrey, op.cit., pp.70-71.
3. For the breadth of his scientific interest cf. Wren, Works, pp.24-33, Speech to Gresham College c.1657, and J.A.Bennett, 'Studies in the Life and Work of Wren'. op.cit. Wren was listed on at least three of the Society's committees for natural histories in 1664, cf. Birch, History, i, 406-407.
4. Sprat eulogised Wren as the embodiment of scientific virtue, cf. History, op.cit., pp.311-318.

intellectual entity) were subsequently affected by Bacon's methodology in only the most general fashion. Although his interest in invention, utilitarian improvement and the rebuilding of London related back to Bacon's motivational influence, his later activities were the product of widely varying factors. Among others these included internal developments within architecture and mathematics, the progress of constructional technology, and the pressure of immediate social requirements. None of these were derived from Bacon's cryptic statements on building and architecture.[1]

Robert Hooke's early intellectual development exhibited almost identical features. He too outlined procedural and structural rules for the proto-Society which were inspired by Baconian experimentalism and natural history.[2] It was Hooke who, in addition to his appointment as Curator, was elected to the Cutlerian lectureship which Sir John endowed 'for the promotion of Mechanick Arts, to be governed and directed by this [Royal] Society'. In 1665 Hooke eulogised Cutler's munificence: 'He hath not only obliged Tradesmen, but Trade itself', adding that 'by this last gift he has done that, which became one of the wisest Citizens of our Nation to accomplish, seeing one of the wisest of our Statesmen,

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1. For Bacon on architecture, see Works, 411-412 (Parasceve), 'Catalogue of Particular Histories', nos. 101, 102, 107, 108, 125; ibid, pp.789-791 (Essays or Counsels Civil and Moral), 'XLV. of Building'. For Wren's science and his transition to architecture cf. J.A.Bennett 'Studies ... in the work ... of Wren' op.cit., pp.269-321. For Wren's continuing interest in invention, coupled with accurate climatological 'histories', cf. A.K.Biswas, 'The Automatic Rain-gauge of Sir Christopher Wren' Notes Recs. Roy. Soc., 22 (1967), 94-104.
2. For Hooke's directions see Sir H.Lyons, The Royal Society 1660-1940, A History of its Administration under its Charters, (Cambridge, 1944), pp.41-42. Further directives by Hooke, from c.1663, are in R.T. Gunther, Early Science in Oxford, Vol.VI, The Life and Work of Robert Hooke, (Oxford, 1930), 121-124. 'The business and design of the Royal Society is - to improve the knowledge of naturall things, and all useful Arts, Manufactures, Mechanick practices, Engynes and Inventions by Experiments ...' See also R.F.Jones, Ancients and Moderns, op.cit. pp.196-199.

the Lord Verulam [Bacon], first propounded it'.[1] Hooke's enthusiasm for the Baconian programme also encompassed natural histories,[2] leading him to say at the end of Micrographia's Preface 'I have at length cast in my Mite, into the vast treasury of a Philosophical History'.

Yet this Baconianism did not, in Hooke's case, remain pristine or unproductive. As a counterpart to his exceptional (and increasingly sophisticated) experimental natural philosophy, Hooke rapidly developed more complex methodological procedures.[3] These, while indebted to Bacon's earlier dicta, refined and ultimately transcended his concepts, incorporating new (continental) elements and problems into the theoretical framework, and following paths dictated by the momentum of individual subjects and the proliferation of contemporary mathematics.[4] Baconianism therefore left a profound mark on Hooke's natural philosophy (as it did on that of Locke,[5] Wallis, et al.), but it did not control its

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1. Hooke, Micrographia, op.cit. 'The Preface', Sig.g.v. For the background to the lectureship, cf. Birch, History, i, 442, 484, 499, 503.
2. Hooke, Micrographia, op.cit. sig. d.r. See also his 'Method for Making a History of the Weather' at Sprat, History, Notes pp.75-78, 'Appendix C'; Keynes: Hooke Biblicgraphy, op.cit. pp.64-65, 75-81.
3. The exact nature of this methodology, unclear because Hooke never gave it complete expression, is slowly emerging. There is, however, an obvious danger that subsequent exegesis overemphasises its clarity and even its concrete existence. Further discussion will clarify whether these modern projections are anachronistic. See, therefore, M.B.Hesse, 'Hooke's Philosophical Algebra' Isis, 57 (1966), 67-83; F.F.Centore, Hooke's Contributions to Mechanics, op.cit. pp.16-40; D.R.Oldroyd, 'Robert Hooke's Methodology of Science as Exemplified in his "Discourse of Earthquakes"'. Brit. J.Hist.Sci., 6 (1972-3), 109-130.
4. For example cf. A.J.Turner, 'Hooke's Theory of the Earth's Axial Displacement: Some Contemporary Opinions', Brit.J.Hist.Sci., 7 (1974), 166-170; J.A.Bennett, 'Hooke and Wren and the System of the World: Some Points Towards an Historical Account', ibid, 8 (1975), 32-61, especially 60-61.
5. For Locke and Bacon cf. K.Dewhurst, John Locke (1632-1704) Physician and Philosopher, A Medical Biography ... (London, 1963), pp.5, 6, 49, 163; P.Long, A Summary Catalogue ... of the Papers of John Locke in the Bodleian Library, (Oxford, 1959) p.37, re : MS. Locke, c.29; F.H. Anderson, The Influence of Contemporary Science on Locke's Method and Results, (Toronto, 1923), pp.1-12.

specific development. Thus, moderating his earlier opinions, Hooke declared in 1674 that by publishing various 'Discourses ... which have no dependencie or coherencie one with another' he hoped:

> 'to avoid any kind of Method or Order that may require Apologies, Prefaces, or needless Repetitions of what is already known ... or may necessitate me to follow this or that Subject, that doth not ... offer itself ... [immediately]. ... This way I chuse as the best for promoting the Design of this Lecture; for there is scarce one Subject of millions that may be pitched upon, but to write an exact and compleat History thereof, would require the whole time and attention of a mans life, and some thousands of Inventions and Observations to accomplish it: So on the other side no man is able to say that he will compleat this or that Inquiry, whatever it be, (The greatest part of Invention being but a lucky hitt of chance for the most part not in our own power, and like the wind, the Spirit of Invention bloweth where and when it listeth, and we scarce know whence it came, or whether 'tis gone'. 1

This attitude came close to contravening one of Bacon's most important principles: the belief that truly rapid technological progress could only be realised through systematic investigation, which was the physical concomitant of a well-structured 'philosophy'.

> 'For all inventions of works which are known to men have either come by chance and so been handed down from one to another, or ... have been purposely sought for. But those which have been found by intentional experiment have been either worked out by the light of causes and axioms, or detected by extending or transferring or putting together former inventions; which is a matter of ingenuity and sagacity rather than philosophy. And this kind, which I noways despise, I will presently touch on by the way ...' 2

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1. R.Hooke, An Attempt To Prove the Motion of the Earth (London, 1674), 'To the Reader' sig.A.3. r & v, in ed. R.T.Gunther, Early Science in Oxford, op.cit., vii, 'Lectiones Cutlerianae', (London, 1679).
2. At Bacon, Works, p.473. Further comments on 'chance' invention and experiment, or simple improvement, occurs at ibid, pp.501, 508, 510.

In other words, by 1674 Hooke denied that technological development could be confidently pre-designated, and questioned the value of Bacon's call for a History of Trades. It was this attitude which lay at the heart of his subsequent dispute with Cutler, a dispute in which Petty played an important role as mediator.

Further evidence of the complex English response to Baconianism can be seen in the work of Robert Boyle. Unfortunately the dictates of space necessarily restrict commentary on this topic, yet even the most cursory analysis of Boyle's prolific writings quickly reveals the deep influence of Bacon's stress on natural history, empiricism and experimentalism.[1] Boyle was a notably enthusiastic member of the Society's committees in 1664, joining seven out of a maximum of eight.[2] Even after their effective demise, and the decline of organised corporate activity in the late 1660s, Boyle continued his research into various aspects of natural history, devoting particular attention to mining and metallurgy.[3] Of all the outstanding natural philosophers in post-Restoration England, Boyle probably retained the greatest reverence for Bacon's programme throughout his career. Although he absorbed material from almost every contemporary scientific source, save the more arcane areas of mathematics, he consciously adopted procedures, and even phraseology, which were derived from Bacon's dicta. Thus, in 1673 Boyle

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1. See Fulton, Boyle Bibliography, op.cit., pp.xix-xx, 'Contents', especially nos. vi, vii, ix, xl, xli and appropriate entries. Boyle contributed his 'General heads for a natural history of a country' to Vol. 1 of Philosophical Transactions, in 1666. cf. Fulton, Boyle Bibliography, p.139, item 210 for locations. See also A.R.Hall, From Galileo to Newton, op.cit. pp.257-260 on the 'Baconian empiricism', of Boyle's experimental physics.
2. Birch, History, i, 406-407.
3. A thorough analysis of Boyle's career-long collection of data on mining techniques, the incidence of minerals etc., is in P.C.Davey 'Studies in the History of Mining and Metallurgy to the Middle of the Seventeenth Century, considered in relation to the progress of Scientific Knowledge and with some reference to Mining in Cornwall' (London University, Ph.D. dissertation, 1954) pp.215-324; see especially 221-245, on Boyle's 'Articles of Inquiries touching Mines' and 286-289.

explicitly reaffirmed his belief in, and support for, experimental natural philosophy, emphasising its utility, the continuing need for a great 'History of Nature', co-operation between Tradesmen and scholars, and many other fundamentally 'Baconian' considerations.[1] In 1691 and 1692, just prior to, and after his death, Boyle's Experimenta et Observationes Physicae and General History of the Air appeared.[2] Both these works were deeply imbued with Baconian concepts, both explicitly referred to this heritage,[3] and both were natural, if much more sophisticated, developments of ideas from Sylva Sylvarum and Parasceve.[4]

Once again the well-established pattern of Baconian influence can be detected, though in Boyle's case this influence was far more conspicuous.[5] Thus it can be said that Bacon left a profound and life-long mark on another leading English natural philosopher. As with Wren and Hooke, Boyle naturally followed paths dictated by current developments in specific subjects, and more readily adopted a hypothetical, or mathematico-deductive line of argument where this concentrated and clarified the problem.[6] Yet many of his basic interests and attitudes were

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1. Boyle, the Usefulnesse of Experimental Naturall Philosophy (1671), Tome II, Section II) op.cit., 'The Preamble', Sig. * 4v-Sig** 4v.
2. Fulton, Boyle Bibliography, op.cit., pp.132-133.
3. Cf. Boyle, Works, (London, 1744 ed.,), v, 77-78, 105-106.
4. Bacon, Works, (Parasceve), pp.409-410, 'Histories by Title', nos. 14, 15, 33, 59, 60, 66 etc. Bacon, Sylva Sylvarum, or, a Natural History in Ten Centuries, (London, Ninth Ed., 1670). Boyle said of Certain Physiological Essays, (London, 1661), in Works (1744 ed.,), i, 196 that 'many of the particulars ...' therein 'were in my first design collected in order to a continuation of ... Sylva Sylvarum'.
5. For concurrence with this statement cf. Jones, Ancients and Moderns, op.cit., pp.162-170; Rogers 'Descartes and the Method of English Science', op.cit., 252-253.
6. Boyle, Usefulnesse of Experimental Naturall Philosophy (1671, Tome II, Section II), op.cit., 'of the Usefulnesse of Mathematicks to Natural Philosophy' (Essay 2) p.3. '... Mathematicks may much help the Naturalist, both to frame Hypotheses, and judg of these that are proposed to him, especially such as relate to Mathematical subjects in conjunction with others'. Boyle regretted his own lack of mathematical training, ibid, pp.1-2.

originally formed by, and continued to operate according to, Baconian desiderata, although, as with other colleagues, Boyle's breadth of reference and methodological appreciation were naturally more complex than those of the great Verulam.[1]

Returning to Petty's involvement with the institutional and topical development of science after 1660, it is clear that he was affected by this familiar interplay between historical events and intellectual heritage. The exigencies of his changing geographical location, individual experience and personal view of science combined unpredictably to channel this involvement and interpose his actions and opinions. Nonetheless, at all levels and in most situations, Petty's serious, Baconian attitude to experimental natural philosophy provided a unifying theme to these apparently incohate scientific interests and activities.

In February 1661 he joyously reported to his cousin John that:

> 'I was, since my last, with ye King, hee seemed earnest enough to speake with mee, I began with a small prologue, among other things telling him, that I never accepted of any trust out of desire or designe to doe him harme, nor had I ever broken any to doe him service, but ye King seeming little to Mind apologies as needlesse replied "But Doctor, why have you left off your Enquiries into ye Mechanick of Shipping". In briefe hee held mee $\frac{1}{2}$ an hower before 40 lords upon ye philosophy of Shipping, loadstone, skreen'd [?] guns, ye feathering of arrowes, ye vegetation of plants, ye history of trades etc. about all which I discoursed intrepide ... In fine wee parted faire and not without cleere signes of future good acceptance ...' 2

Concurrently he was involved with the activities of the proto-Society, conducting joint experiments on shipping, pendulums and gravity.[3] More

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1. For example, despite a disclaimer about early restriction of literary sources, Boyle's 'Proemial Essay [on] Experimental Essays in general', Works, (1744 ed.) i, 192-204, reveals great erudition and awareness of sources both classical and contemporary.
2. B.H. MSS. Volume 6, Section 1, letter xix, 5 February, 1661.
3. Birch, History, i, 7, 22, 74-75.

important, perhaps, was his contribution to the establishment and formulation of the institution's procedural and structural organisation. As we have seen, Petty's view of a scientific society's function rested upon a deep appreciation of Bacon's earlier vision. This picture of a state corporation, co-ordinating the efforts of its members in systematic programmes of socially valuable scientific research, remained with him throughout his life. Between 1660 and 1687 it was clearly manifested in his enthusiastic support for the Society's History of Trades project, and his essays and miscellaneous collections which were inspired by this most Baconian of concepts.

In 1660 Petty's interest in the History of Trades reflected a long-standing commitment. As early as 1647 Hartlib had recommended him to Boyle on the strength of this commitment, referring to Petty's Advice as 'the design of the History of Trades' and proposing that Boyle give financial support to the scheme.[1] During these London years Petty produced comprehensive lists of different trades, which exceeded Bacon's version in Parasceve,[2] and equalled that collected by Evelyn in the late 1650s.[3] An important feature of this project was Petty's enthusiastic fraternisation with tradesmen, which was shared by Robert Boyle, but later proved socially unacceptable to Evelyn.[4] Petty's belief in the History of Trades remained constant during his Irish 'exile', to the extent that Robert Wood inherited this compulsion as a result of their friendship in 1656.[5] Five years later he reported to Hartlib:

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1. See above, p. 76.
2. Bacon, Works, pp.409-412, and B.H. MSS. Volume 3, item 11(b), ff.1-2r.
3. Cf. A.Forbes-Sieveking 'Evelyn's "Circle of Mechanical Trades"', Trans. Newcomen Soc., 4 (1923-24), 40-47.
4. Cf. Petty's list c.1647-8, with the names of associates, and a description of their trade, at B.H. MSS. Volume 3, item 2. For Boyle's belief in the value of the History, cf. Usefulnesse of Experimental Natural Philosophy (Tome II, Section II, 1671). op.cit., 'The Preamble' and Essay 1. Evelyn's famous letter about 'mechanical capricious persons' is in Diary [and Letters] of John Evelyn, ed. H.B.Wheatley (London, 1879) iii, 260-261, letter to Boyle 9 August, 1659.
5. Hartlib Papers, xxxiii, 1, f.4r, letter Wood to Hartlib, 10 June, 1656.

> '... I heartily wish that the History of Trades, or Arts Mechanical might be compiled by those able hands you mention, I know ye Dr [Petty] has had many thoughts of it long since...' 1

Thus, during the Society's first few years, Petty, joined by colleagues like Boyle, Hooke, Evelyn and Wren, shared a growing conviction that Bacon's programme for natural histories, and especially a History of Trades, was the most urgent task facing the institution.[2] In Petty's case this enthusiasm rested on concepts which had remained in suspended animation during the long years in Ireland, and which possibly reflected a scientific naivite unaffected by the new sophistication fostered in the Down Survey.

Every adherent of the project shared the common currency of Bacon's philosophy,[3] and each outlined his own interpretation of that philosophy. For his part, Petty gave one of the earliest expressions of a personal view in various sections of the Advice. One of the central institutions described in this tract was a 'Gymnasium Mechanicum' or 'Colledge of Trades-men' which would house the most accomplished exponent of each 'Mechanicall Art and Manufacture'. The cohabitation of these master-craftsmen would, through cross-fertilisation of ideas, lead to a 'miraculous' development of existing trades and the invention of new ones. In addition Petty maintained that:

> 'Here would be the best and most effectual opportunities and meanes, for writing a History of Trades in perfection and exactnesse, and what Experiments and Stuffe would all those Shops and Operations afford to Active and Philosophicall heads, out of which, to extract that Interpretation of Nature, whereof there is so little, and that so bad as yet extant in the world?' 4

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1. Hartlib Papers, xxxiii, 1, f.74r, letter Wood to Hartlib, 23 March, 1661.
2. Cf. W.E.Houghton 'The History of Trades', op.cit., 50-57.
3. Cf. Bacon, Works, pp.81 (Advancement of Learning, 1605); 405-406 (Parasceve, 1620); 429 (De Augmentis Scientiarum, 1623); cf. also Houghton, 'History of Trades' op.cit. 34-38; Webster, Instauration, pp.424-5.
4. Petty, Advice, p.7.

Later in the pamphlet he gave a precise description of how a History of Trades, as part of the 'Vellus Aureum Sive Facultatem Luoriferarum [sic] discriptio Magna', should be compiled and organised. The section dealing with the 'History of Arts and Manufactures' would provide a complete, but concise, description of each discrete trade or skill, and would be accompanied by accurate, full colour illustrations. Duplication was to be avoided at all costs, thus obviating prolixity, and an elaborate system of cross reference would facilitate inter-disciplinary usage. Terminological standardisation and descriptive accuracy were seen as absolute prerequisites. To put these ideals into practice it was essential that a single director should be appointed to control the project. In 1648 the ambitious author of the tract obviously believed that he was the perfect candidate for this executive post:

> 'The Compiler must be content to devote his whole life to this employment, one who (as we said before) hath the fire of Industry and the Alembick of a Curious and rationall head, to extract the Quintessence of whatsoever hee seeth' 1

After completing this outline, Petty provided an exhaustive list of the social and intellectual benefits to be derived from the History. Leaving aside the educational, mathematical and economic aspects of such benefits, it can be seen that the other raisons d'etre fall into two categories: the diffusion and development of technology, and the provision of concrete material on which persons interested in natural philosophy could build experiments and test new hypotheses. Petty hoped that the project would enable lawyers, gentlemen and other non-specialists to understand the practical aspects of various trades. Above all there would be:

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1. Ibid, pp.18-26, quotation from p.24.

> 'a vast increase of honourable, profitable and pleasant Inventions ... when one Man (as the Compiler thereof) may uno intuitu, see and comprehend all the Labour and Wit of our Ancestors, and be thereby able to supply the defects of one trade and the perfections of another'. 1

In addition he believed that:

> '3. Schollers and such as love to Ratiocinate will have more and better Matter to exercise their wits upon, where-as now they pusle and tire themselves, about meer words and Chymaericall Notions.
> 4. They will Reason with more alacrity, when they shall not only get honour by shewing their Abilities, but profit likewise by the invention of fructiferous Arts.
> 5. Sophistry shall not be in such esteem as heretofore when even Sence shall be able to unmask its vanity, and distinguish it from Truth'. 2

Finally, in true Baconian fashion, he predicted that:

> 'This History with the comments thereupon, and the Indices, Preface and Supplements thereunto belonging would make us able (if it be at all possible) to demonstrate Axioms in Philosophy, the value and dignity whereof cannot be valued or computed'. 3

Thirteen years after publication of the Advice, Petty returned to the project, though this time in a communal effort under the auspices of the Society. Enthusiastically supporting the programme for Baconian histories, Petty compiled new lists,[4] provided two contributions

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1. Ibid, p.22.
2. Ibid, p.22.
3. Ibid, p.26.
4. An example of these (c.1661-2) lists is at B.H. MSS. Volume 1, item 37, reprinted in Lansdowne, Petty Papers, i, 205-207. Comparison between this list and those located in the Hill Papers at Brit. Mus. Sloane MSS. 2903, ff.59-60, and especially 63-66, reveals that they have been incorrectly ascribed to Petty; ff.59-60, are in Hill's hand, and were probably by him, ff.63-66 is his copy of Evelyn's 'history of Arts illiberal and mechanique', of which another copy is in Royal Soc. MSS. Classified Papers, Vol.iii, (1), item 1, reprinted in Forbes-Sieveking, op. cit.

to the History of Trades (in November 1661 and May 1662) and was elected to four of the committees in 1664.[1] He was also chosen to represent the Society, with other Fellows such as Graunt, Hill and Hoskyns, in negotiations which preceded the foundation of the Cutlerian lectureship.[2] Petty's two Histories concerned subjects which he was technically well qualified to describe: viz. 'Of making cloth with sheeps wool'[3] and 'An Apparatus to the History of the Common Practices of Dying'.[4] While in no way approaching the powerful and comprehensive format envisaged in his early scheme, these essays do possess certain merits and are representative of the limited products of the Society's programme.

By the mid-seventeenth century dyeing was one of the more significant trades in England, since it was a necessary adjunct to the major industrial process of cloth manufacture.[5] This significance was enhanced as new types of cloth, requiring the use of a wider variety of dye-stuffs, came into prominence. As demand for the dyer's skills grew more acute, and as profitability came to depend on these skills, so there developed a need for technical literature describing basic processes and modern improvements. A century earlier, the burgeoning industries of Northern Italy had also created a similar need for such literature, and consequently the great works by Biringuccio, Agricola and Rosetti had appeared. Rosetti's Plictho went into five Italian editions between 1548 and 1672, which is a strong testament to its

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1. Cf. Birch, History, i, 55, 83, 406-407.
2. Birch, History, i, 442, 484, 499, 503.
3. Original copy located at B.H. MSS. 36, Box G, item 7, printed in Birch, History, i, 55-65, delivered 27 November, 1661; another copy at Brit. Mus. Sloane MSS. 2903, ff. 26r.-38v.
4. Copies at B.H. MSS. 40, Box K, item 6, i + ii; Brit. Mus. Sloane MSS. 243, ff.38.-; Printed Sprat, History, 284-306; other copies at the Royal Society, cf. ibid, Notes, p.53, (for text, p.284).
5. Cf. G.D.Ramsay, The Wiltshire Woollen Industry, (London, 1943), pp.91, 103-116, 129-131; J. de L.Mann, The Cloth Industry in the West of England from 1640 to 1880, (Oxford, 1971), pp.xii-xiii, 8-14; L.G. Lawrie, A Bibliography of Dyeing and Textile Printing, 1500-1946, (London, 1949).

enduring utility.[1] Unfortunately the tract was not translated into English during this period, and its great erudition on dyeing techniques remained unavailable to those tradesmen and entrepreneurs who most needed it. Instead, this expanding group had to rely on manuscript sources, word-of-mouth recipes, and a few imprecise tracts like Mascall's A profitable booke how to die Velvets and Silks.[2] Significantly, this was the translation of a treatise from the Low Countries. A major step forward came around 1630 when Cornelius Drebbel discovered a new process using a tin mordant for dyeing scarlet with cochineal.[3] At the same time there appears to have been an acceleration of interest in the technology of dyeing, which Plattes, Hartlib, Petty and Beale reflected in published and manuscript works.[4] However, by 1661 there had been few valuable additions to the scanty reserve of published information. Naturally enough, the Royal Society identified this need and attempted to answer it as part of the History of Trades programme.

On 7 May 1662 Petty presented his Apparatus [on] Dyeing,[5] and a week later the Society asked 'Mr Haak ... to translate an Italian treatise concerning dying' which was probably Rosetti's Plictho.[6] After four

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1. Cf. Georgius Agricola De Re Metallica, trans., and ed., H.C. and L.H. Hoover (New York, Dover Reprint, 1950), pp.vi-xviii; The Pirotechnia of Vannoccio Biringuccio, trans., and ed., C.S.Smith (New York, 1959), pp.ix-xxv; The Plictho of Gioanventura Rosetti, Intructions in the Art of the Dyers, trans. S.M.Edelstein, H.C. Borghetty (Massachusetts, 1969), pp.xi-xx.
2. Printed in London, 1583, a translation of T'bouck Va[n] Woudre (Brussels, 1513). Cf. Plictho, op.cit., p.xi. Aubrey's copy at Bodleian Library, M.S. Ashmole 1672, v, (1583 ed.)
3. Cf. J.R.Partington, A History of Chemistry, (London, 1969), ii, 324.
4. G.Plattes, A Discovery of Subterraneall Treasure, (London, 1639), pp.52-59; Hartlib Papers, li, ff.107-144, Beale's ms. treatise on dyes and inks; ibid, xxvii, 13, f.7. Kuffler's agreement to supply Mr. Harle with the 'mystery of the Scarlet die' for £100; ibid, lii, f.149, anonymous latin recipe for dyeing with cochineal; ibid, lxxi, 9, f.1. short note, headed 'Dr Pitty', undated but (?) c.1650, containing Petty's comments on 'Indian Secrett' of colour-fast dyes.
5. Birch, History, i, 83.
6. Ibid.

months, because of delay or difficulty on the part of the translator, a further order was made that 'Sir Gilbert Talbot, Dr Merret, Mr. Haak, and Mr Henshaw [be] desired to assist in the Translation of the Italian book about dying'.[1] As with the subsequent committee on agriculture,[2] collaborative effort proved to be ineffective and the translation failed to materialise. Four years passed before the question of dyeing was raised again. In May 1666 Sir Theodore de Vaux introduced further material on 'colouration' and an ad hoc committee, which also included Hooke, Ent, Coxe, Colwall, Oldenburg and Quatremain, was convened to collect further information.[3] This group compiled an impressive body of material, including manuscript formulae and tracts,[4] and Oldenburg published a few fragments from this canon over the next few years.[5] However the appearance of two short essays in the Philosophical Transactions only heightens the committee's failure to produce a major work. Instead, the Society's investigations (both published and unpublished) on dyeing and colorific theory, or parallel research into the nature of light, depended on the initiative of individuals like Petty, Hooke and Boyle[6] in the 1660s, or Newton,

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1. Ibid, 109, 3 September, 1662.
2. Cf. R.Leonard, 'English Agriculture', op.cit.
3. Birch, History, ii, 93, 23 May, 1666; ibid, 97, 13 June, 1666.
4. Material at Roy. Soc. MSS. Classified Papers, iii, (1), 27-41. Much information came from Sir Theodore Mayerne's papers, and related to the work of Lemoy in the 1630s. Item 40 contains a list of books (in French), including the Plictho. See also Roy. Soc. MSS. Classified Papers, xxiv: 'Hooke, Collins, Oldenburg, 1660-1740', 80-83, containing a major treatise on dyeing in Hooke's handwriting, which is probably the most extensive seventeenth century English work on the subject. Many of the notes also date from c. 1630-1640.
5. Philosophical Transactions, xx, (17 December, 1666), 360-363; ibid, xl, (19 October, 1668), 796-797.
6. R.Boyle, Experiments [on] Colours, ... The Beginning of an Experimental History of Colours, (London, 1663). Boyle deliberately excluded any consideration of the 'lucriferous practices of dyers and other tradesmen' from the treatise. Cf. Works (1744 ed.), ii, 79, 'Experiment XLIX,: Annotation iv'; cf. Partington, History of Chemistry, op.cit, ii.511-512. For Hooke's demonstration of various dyes 9 December, 1669 cf. Birch, History, ii, 411.

Lister and Ray in the 1670s,[1] and on Cole and Waller[2] in the 1680s. It therefore remained for a figure from outside the institution to produce an extensive work dealing with practical problems, and thus William Salmon's Polygraphice: Or the Art of Drawing, ... Colouring, Dying ... and Perfuming appeared in 1672, reaching a fifth, enlarged edition by 1685. This preparatory historical account helps to reinforce the contention that the Society's programme for a History of Trades failed to achieve its aims. Although continuing interest was shown in the technology of dyeing, this was an expression of individual, as opposed to corporate concern, and was popularised through ad hoc publication in the Philosophical Transactions.

Written during the early years of corporate enthusiasm, Petty's short treatise on dyeing stands as a model of systematic planning and concise enumeration, rather than solid literary achievement. When compared with the Plictho, or De Re Metallica, its diminutive size, and lack of formulae and illustration becomes tritely apparent. Yet to contrast it with such illustrious precedents is neither illuminating[3] nor

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1. For Newton on the theory of light see Philosophical Transactions, lxxxviii, (18 November, 1672) and Chapter 3, p.268. below. For Lister on dyeing, cf. Philosophical Transactions, lxxv (18 September, 1671), 2256; ibid, lxxx, (19 February, 1672), 3090-3092; ibid, lxxxvii, (14 October, 1672), 5059-5060; Oldenburg, Correspondence, vii, (letters c.1670-1672), 459-461, 474-475; ibid, viii, 69-71, 105-107, 137-138, 212-213. For Ray's interest in dyeing cf. ibid, vii, 384-387.
2. For Cole cf. Philosophical Transactions, clxxviii (December, 1685) 1278-1286, and A.J.Turner, 'Purpura anglicana: A Bibliographical Note', Soc. Biblp'hy nat. Hist., 5 (1970), 361. For Waller's 'A Catalogue of Simple and Mixt Colours ...' cf. Philosophical Transactions, clxxix, (February, 1686) 24-28. Further material on the Society's interest in dyeing c.1680-1730 is in: L.Trengrove 'Chemistry at the Royal Society of London in the Eighteenth Century - iv, Dyes' Ann.Sci., 21 (1965), 331-353, especially 332: '... naturalists found new dyes and acquired more information about old ones, but the contribution of chemists was severely limited by the inadequate means of organic analysis available to them'.
3. Cf. F.Brunello, The Art of Dyeing in the History of Mankind (1973, Vicenza), pp.204-220, especially p.205. 'In this he [Petty] accurately describes all the methods employed by the best Italian and Flemish dyers of the period. Petty's [tract] was undoubtedly an important means for the up-dating of the method of British artisans.'

judicious. A more appropriate comparison might be made with Pell's Idea of Mathematics[1] (also a plan for future research), or Salmon's Polygraphice. As the first English work to categorise dyeing procedures and materials, the Apparatus far exceeded Leonard Maschall's profitable book. Adopting the 'natural history' approach, Petty disclaimed any intention of examining the theory of colour and light. Instead he began by listing the various types of colorific process, and then described in greater detail the mineral, chemical, animal and vegetable ingredients which were used as mordants, dyes or agents for textile cleansing and stiffening. Particular attention was paid to the chemical effects of alum,[2] and a provisional explanation of its fixative powers, based on a particulate theory of matter, was provided. The penultimate section dealt in greater detail with the basic dyes, especially those of vegetable origin, and the essay concluded with some 'General Observations upon Dying'. Among these final comments Petty called for accurate, experimental measurement of ingredients and procedures:

> '19. There is little reckoning made how much Liquor is used in proportion to the dyeing Drugs; the Liquor being rather adjusted to the bulk of the Stuff, as the Vessels are to the breadth of the same: The quantity of dying Drugs being proportioned to the colour higher or lower, and to the Stuffs both; as likewise the Salts are to dying Drugs. ... I conceive much light would be given to the Philosophy of Dying, by careful experiment of the weight added by each Drug in Dying of every colour'. 3

In the last two paragraphs Petty recognised the essay's defects, promising further exegesis of the 'Vessels, Tools and Utensils' properly belonging to the trade. Despite his admission of these faults and of

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1. P.J.Wallis, 'An Early Mathematical Mainifesto ...' op.cit.
2. See Charles Singer : The Earliest Chemical Industry : An Essay in the Historical Relations of Economics and Technology illustrated from the Alum Trade, (London, 1947) for the importance of alum, and pp.255-260, 'Chapter 5. Beginnings of Scientific Dyeing', especially pp.255-256 for Petty on alum, Boyle's Experimental History of Colours, and Hooke's experiments c.1669.
3. Petty, Aparatus, in Sprat, History, pp.304-305.

the complex problem involved in writing on such a skilled and varied subject, Petty's achievement was notable. To quote Singer's judgment: 'Petty ... [ended] ... this Apparatus with the most complete and systematic short account of the practice of dyeing that appeared in any language for the next hundred years'. The final sentence of Petty's essay, however, contained a call for more ambitious co-operative research:

> 'But this [aspect of dyeing] being infinite, and almost unteachable by words, as being incomparably more difficult, than how to imitate and compose any Colour assigned, out of the few, usually furnishing a Painter's-palat; I leave the whole to the further consideration of this Learned Society'. 1

Unfortunately, it became obvious after 1667 that the Royal Society was constitutionally incapable of undertaking such research in a systematic fashion. One of Petty's basic aims for the institution was therefore frustrated. Nonetheless, he himself never lost this deep personal commitment to the scientific enumeration and investigation of technology, which was an integral part of the History of Trades. As his short tract on weaving demonstrates he was capable of writing clear and concise expositions on the wide range of technical subjects of which he was a master.[2] Yet even these hopes foundered on the chaotic distractions of business and, despite the accretion of a large amount of miscellaneous material on different trades,[3] he failed to produce any tangible results

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1. Singer, Alum, op.cit., p.256 and Petty, Apparatus, in Sprat, History, p.306. See also ed. C.Singer et.al. A History of Technology, (Oxford, 1957), iii, F.W.Gibbs 'Invention in Chemical Industries', 676-708, especially 692-695.
2. J. de L.Mann, The Cloth Industry, op.cit., pp.284-287 quotes Petty's treatise on cloth making as a reliable and accurate source for details of the industrial practices in the West of England.
3. This information on tanning, salt-making, dyeing, printing, etc., which is too extensive to itemise, is primarily located at B.H. MSS. 36 Box G, folders 1, 3, 5, 7, and ibid, 40, Box K, folder 6. The dyeing materials contain a number of detailed recipes and formulae for specific processes, including one for Drebbel's famous 'Dying of Scarlett'.

during his later years. Nonetheless, it is against this fundamental commitment that much of Petty's subsequent activity must be viewed. Although fragmentary and unproductive, this was entirely characteristic of the man and the period, and many of his brief essays and plans for writing or research should be included within this category. Once this identification has taken place, Petty's published and unpublished schema, dating from 1670 to 1687,[1] take on a new coherence that reflects a common intellectual heritage. Thus, the ambitious Baconian technologist of 1647 was changed by circumstance into the distracted, frustrated and care-worn natural philosopher of the 1680s. The major qualitative differences between the two was the latter's preponderant concern for quantification and measurement (exemplified in the Discourse of Duplicate Proportion), and his air of resignation at the continual disappointments of life.

At first sight it might appear that Petty's experience was matched by that of the Society, for the 1664 committees failed to produce a single important work. Yet to argue that their incompetence and ignominious performance was accompanied by a correspondingly rapid decline in the Fellows' concern for technology or natural history, is manifestly false. On the contrary, these deeply held methodological predications were re-affirmed time and time again by the activities of individual Fellows and the publication of works sanctioned, received or dedicated to the Society and its members. Boyle's continuing re-

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1. This category should include Petty's 'Queries to examine Mineral Waters', Philosophical Transactions, clxvi (20 December, 1684), 802-803; 'Miscellaneous Catalog of Mean, Vulgar, Cheap and Simple Experiments, (Dublin, 1684); 'Catalogue of Experiments drawn up [for] the Dublin Philosophical Society', Philosophical Transactions, clxvii (28 January, 1685), 849-853; 'Supellex philosophica' in Birch, History, iv, 397-398; 'List of Subjects for Essays', in Lansdowne, Petty Papers, ii, 266-269; 'Natural Observations', ibid, 218-226; 'Of Fire' ibid, 200; 'Enquiries Concerning Bathe Waters' at B.M. MSS, 36, Box G, folder 4.

searches into the mining industry and associated phenomena, when added to other contributions between 1665 and 1685, make a most impressive collection of specialised technical literature.[1] Joseph Moxon, who became a Fellow in 1678, was the author of a flood of instructional tracts,[2] including an exemplary account of printing which became the definitive work on typography for over a century,[3] and a second on the crafts employed in housebuilding, which reached a third edition by 1703.[4] John Houghton, who was elected in 1680, successfully produced a journal called A Collection for the Improvement of Husbandry and Trade,[5] which received the explicit support of twenty-seven leading Fellows on 11 November 1691.[6] John Worlidge, an outstanding agricultural author, published his Systema Agricultura,[7]

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1. P.C.Davey 'Studies in the History of Mining', op.cit., 215-324 'Chapter 5: The Royal Society : Interest in Mining and Metals'.
2. Cf. British Museum Catalogue of Printed Books, (London, 1965) clxv, columns 759-761 for the fifteen separate works by Moxon concerning mathematics and technical subjects.
3. J.Moxon, Mechanick Exercise or the Whole Art of Printing, (London, 1683-4), ed. H.Davis, H.Carter (London, O.U.P, 2 ed. 1962), 'Introduction'. C.S.Bliss, Some Aspects of Seventeenth Century English Printing with special reference to Joseph Moxon (Los Angeles, 1965).
4. J.Moxon, Mechanick Exercises: or the Doctrine of Handy-Works, Applied to the Arts of Smithing, Joinery, Carpentry, Turning, Bricklaying ... (London, 3rd. ed., 1703), first published 1678-1679, reprinted 1693-1701 with additions.
5. Published 1681-1683, re-commenced 1691; last issue 24 September, 1703, (No. 583); Collected edition (London, 1727), in three volumes. For Houghton, cf. D.N.B.
6. Houghton Collected Edition, op.cit., i, p.4; list included Evelyn, Plot, Grew, Tyson, Sloane, Lodwick, Halley, Southwell, Pepys, Hoskins, Pett, Sloane, et. al.
7. Editions, published in London, in 1669, 1675, 1681, 1687 etc; the work expanded with each new publication. Cf. Lord Ernle, English Farming Past and Present, (London, 5th ed., 1936) pp.130-131, noting that despite defects, this work, and others which it summarised, were remarkable for their advocacy of improvements which became common only a century and a half later. For Worlidge, cf. D.N.B.

a popular and authoritative book, which was deliberately linked to the Society's activities. In the preface he suggested that subordinate educational institutions should be created throughout the country to 'collect all such Observations, Experiments, and Improvements they finde within their Province, relating to this or any other Art within their Inquiry'.[1] They would then circularise this research, using the parent Society in London for co-ordination and direction.

Nehemiah Grew, seventeenth-century England's outstanding plant anatomist and a leading exponent of botanical natural history, was also fascinated by the practical application of his research and the development of technology.[2] Martin Lister, a founder of the sciences of geology, conchology, and associated fossiliferous theories (themselves conscious developments of the English natural history tradition),[3] called for countrywide, geomorphological soil maps and also wrote his unfinished 'Methode for ye Historie of Iron' whose fourth chapter appeared in the Philosophical Transactions of 1693.[4] This journal was itself a major vehicle for the popularisation of books or material on technology and natural history, and contained innumerable references to both subjects under a succession of editorial hands which

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1. Worlidge, Systema Agricultura, (London, 1687), The Preface.
2. For Grew as botanist and anatomist see p. 136 n. 4 above; for his suggestions on medical natural histories see p. 229 below; for Grew's interest in the mechanical properties of timber, and scientific felling, cf. L.Sharp, 'Timber, Science, and Economic Reform ...' op.cit., p.72.
3. For a summary of Lister's life and works cf. M.Lister, A Journey to Paris in the Year 1698, ed., R.P.Stearns (Illinois, 1967), Introduction, especially pp.lv-lvi, which quotes Lister's Baconian account of the methodology employed in his natural histories.
4. Cf. ibid, p.292, describing the Lister MSS. at the Bodleian Library; Philosophical Transactions, cciii (September, 1693), 865-870, for 'The Manner of making Steel and its Temper'; ibid, cxliv (October, 1684), 739-746, for soil maps; see also J.S.Carr 'The Biological Work of Martin Lister (1639-1712),' (Ph.D. Thesis, Leeds University, 1974).

included Oldenburg, Grew, Hooke, and Plot.[1] Christopher Merrett, whose Art of Glass[2] (a translation of Neri's earlier treatise) appeared in 1662, produced two Latin editions in Amsterdam (1668, 1686), substantially adding to the original work. In 1679 Kunckel combined this with his own book on glass to produce a masterpiece. Merrett also compiled and published Pinax Rerum Naturalium Britannicarum (1667) and provided material for the Philosophical Transactions on Cornish tin mines and refining.[3] As might be expected of a friend of Boyle and a dedicated Baconian, Merrett continued to pursue avenues which, if not dictated by the great Verulam, were at least obvious developments of his programme.

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1. The exigencies of space disallow extended reference to this feature of the journal. Nonetheless, as examples, cf. Philosophical Transactions, lxi (18 July, 1670), 2008-11 for Oldenburg's review of W.Clarke, The Natural History of Nitre, (London, 1670); ibid, lxvi (12 December, 1670), 2034-2036, review of J.Webster, Metallographia, or an History of Metals (London, 1670); ibid, cxxiii (25 March, 1676), 568-570, review of Sydenham ... Morborum Acutorum Historiam ... (London, 1676). In this volume Oldenburg complained that a 'Natural History of Countries is most wanting ...', Philosophical Transactions, 'Preface' to volume 11. Grew continued the tradition, cf. ibid, cxxxviii (25 March, 1678), 967-968, review of Moxon: Mechanick Exercises (London, 1677-); so did Plot, thus, ibid, cxlvii, (10 May, 1683), 189-194, for the review of Sir J.Pettus (trans.) Fleta Minor ... (London, 1683); Hooke's 'Preface' to Philosophical Collections, (London, 1680) noted 'The Discovery of useful Truths in Nature and Art is aimed at'. Consequently at ibid, iv, (10 December 1681), 80, he reviewed M.A. della Fratta, Prattica Minerale (Bologna, 1680) which he noted was derived from Agricola, and of great utility.
2. C.M. The Art of Glass ... Written in Italian by Antonio Neri, and translated into English, with some observations on the Author. (London, 1662) Cf. Lister's annotated copy at Bodleian Library, Lister A.235; cf. Partington, History of Chemistry, op.cit., 368 for Dutch editions. For Merrett's limitations as a natural historian cf. C.E.Raven, English Naturalists from Neckham to Ray (Cambridge, 1947), pp.311-338. For details of Merrett's life cf. Munk, College, 258-264.
3. Balle, Croune and Merrett scrutinised Colepresse's paper on mining in the South-West in October and November, 1667. Cf. Birch, History, ii, 195, 199, 201, 202, 208. Paper on tin-mines registered on 16 December, 1663 publication deferred until Philosophical Transactions, cxxxviii, (March 1678), 949; for Merrett's paper on refining, cf. ibid, cxlii. (December 1678 - February 1679), 1046-1052.

The inheritors of the Baconian tradition therefore varied enormously in their scientific capabilities and over the subjects which interested them. They included among their ranks men like Aubrey, Plot, Boyle and Barrow, and the works which bore some relation to this tradition could range from John Graunt's remarkable: Natural and Political Observations ... upon the Bills of Mortality, to that by the anonymous 'W.B.' whose Touchstone for Gold and Silver Wares or, A Manual for Goldsmiths, was dedicated to Sir Joseph Williamson, a leading F.R.S.[1] Yet, given the preceding information, it is clear that the development of the natural history genre, the History of Trades, and an involvement with technology were outstanding features of post-Restoration science. While it is naive to suggest that this was wholly due to Bacon, as John Ray's training and progress would indicate,[2] or to deny the existence of powerful alternative traditions, as demonstrated by C.E.Raven's work on early naturalists, or E.G.R.Taylor's book on the mathematical practitioners,[3] it is equally naive to dismiss Bacon's pervasive influence. Among many English natural philosophers between 1640 and 1690 there was an evident response to, and absorption of, fundamental aspects of Bacon's system, despite his demonstrable lack of detailed scientific achievement (a feature well illustrated by the unsystematic and non-experimental nature of Sylva Sylvarum).

Thus, there was a real, if tenuous, link between Sir Thomas Browne's

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1. For Graunt's famous work, published London, 1662, cf. Keynes, Petty Bibliography, pp.75-82, and Chapter 4, p. 363 below. A Touchstone (London, 1677) reviewed Philosophical Transactions, cxxxii (February, 1677), 814.
2. See Charles Raven's magisterial John Ray Naturalist: his Life and Works (Cambridge, 1942). Ray's training was in Cambridge, between 1644 and 1658, where Bacon's philosophy had less impact than at Oxford.
3. Raven, English Naturalists, op.cit., pp.1-227. Raven's great knowledge of the earlier tradition of natural history, especially botanical subjects, led him to underestimate the influence of Bacon. Hence his lack of understanding about Merrett's motive for natural history and the History of Trades (ibid, p.311), his dismissal of Bacon (ibid, p.340), and unsatisfactory treatment of English natural history, in its broader framework, from 1640-1690. At no point does Raven refer to R.F.Jones, Ancients and Moderns, (first published 1936), the best early study of this aspect of Bacon's influence.

Pseudodoxia Epidemica and Edmund Halley's pioneering research on wind-charts, oceanic currents and hydrology, in that both inherited, immediately or unconsciously, scientific attitudes and directives provided by Bacon. In Browne's case these influences were tangential, so that his approach to method and scientific knowledge lacked the rigour demanded by the Baconian System.[1] However, forty years later the effects of this system, reinforced by continental influences, were deeply rooted. Thus, Halley's quantitative procedures, and some of the subjects on which they operated,[2] were directly foreshadowed by Bacon's plan in Parasceve:

> '... everything relating both to bodies and virtues in nature [should] be set forth ... numbered, weighed, measured, defined. For it is works we are in pursuit of, not speculations; and practical working comes of the due combination of physics and mathematics. And therefore the exact revolutions and distances of the planets - in the history of the heavenly bodies; the compass of the land and superficial space it occupies in comparison of the waters - in the history of earth and sea, how much compression air will bear without strong resistance - in the history of air ... and numberless other particulars of that kind are to be ascertained and set down'. 3

That Halley was one end-product of an English tradition, incorporating systematic natural history, precise enumeration, empiricism and experiment-

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1. Cf. R.H.A.Robbins 'Some Co-operating Advances: The Seventeenth-Century Context of Sir Thomas Browne's "Pseudodoxia Epidemica", in Essays Presented to C.M.Bowra, (Oxford, 1970), pp.61-62; E.S.Merton, Science and Imagination in Sir Thomas Browne, (reprinted, New York, 1969), 18-25, and index 'Bacon'.
2. For Halley's work on these subjects cf. E.G.R.Taylor, The Haven-Finding Art (London, 1958), pp.238-240; A.K.Biswas 'Edmond Halley, F.R.S. Hydrologist Extraordinary' Notes Recs. Roy. Soc., 25 (1970), 47-57; for Halley's eclecticism as a natural philosopher, cf. E.F.MacPike, Correspondence and Papers of Edmond Halley (Oxford, 1932), especially pp.272-278 giving a bibliography of his publications. See also C.A. Ronan, Edmond Halley: Genius in Eclipse (London, 1970) especially, p.79; G.M.Rodgers, 'Official English Maritime Explorations 1660-1780: A Study of the Beginnings of Scientific Expeditions' (Ph.D. dissertation, University of Texas, 1958), pp.61-70.
3. For Bacon's call for climatological and hydrological histories cf. Works, p.409, 'Catalogue of Particular Histories by Titles'. nos. 5-12, 16-18, 20-21 (Parasceve); quotation from Works, p.406, (Parasceve)'Aphorism vii' For the development of oceanography and the role of Bacon, Boyle, Halley, Hooke et.al, cf. M.Deacon, Scientists and the Sea, 1650-1900, A Study of Marine Science (New York, London, 1971), pp.71-174.

alism, which owed much to Bacon, is not now open to serious doubt. However, for him, as for Hooke, Wren, Grew, Boyle, Locke or Wallis, this influence varied in intensity, and was transmuted by personal inclination and the evolution of increasingly distinct subjects, into channels or methods far more sophisticated than Bacon's original concepts. In general, it can be argued that the more outstanding the natural philosopher, the further was his progress beyond Bacon's original dicta, and the more stimulating and varied were his sources. Yet Bacon's influence, and the social and motivational substratum which that represented and engendered, helped originate a significant, even unifying dynamic to this great period of English natural philosophy. Perhaps, therefore, it was the decline of this empirical, experimental, and socially responsive ethos which, compounded by the barbs of the satirists and shifts in intellectual fashion, encouraged the decay of English science at the end of the century.[1]

Whatever its detailed history and extent, it is clear that William Petty's activities and writings form an integral part of this tradition. Although his major contribution after 1660 consisted of economic and sociological works (described in a subsequent chapter), it should be recalled that these were as much an extension of Bacon's programme, as a synthesis of personal experience and alternative intellectual influences. The less important, and certainly less successful, side of Petty's efforts after 1660 also fit into this pattern. Thus his contribution to the early organisation of the Royal Society, his support for the History of Trades, and his continuing habit of compiling lists of experiments, trades,

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1. For a brief survey of evidence that supports this contention cf. M. Espinasse 'The Decline and Fall of Restoration Science', Past and Present, 14 (1958), 70-89. For an interpretation of vols. i-iii of Oldenburg's Correspondence that pointedly, and uninformedly rejects the theme presented in the preceding part of this section, cf. Q. Skinner 'Science and Society in Restoration England', The Historical J 10 (1967), 286-293.

and projected essays which were never completed, naturally fall within this category. This also applies to his designs for both the Royal, and the Dublin Philosophical Society in 1684 and 1687.

Petty's relationship with William Molyneux, Dublin's leading natural philosopher in the later years of the century, and his attempt to organise the Dublin Philosophical Society along modified, but strictly Baconian lines, provide an illuminating insight into the development of British natural philosophy in the 1680s. Molyneux, like his good friend and colleague Edmund Halley, was also a product of the English scientific tradition outlined above. The most recent accounts of his career and attitudes have clearly established Molyneux's utilitarian, experimental and empirical methodology.[1] At the same time, this young natural philosopher, whose collection of Baconiana took 'pride of place'[2] in his library, received enormous benefit from the widest possible range of contemporary sources, which included works by Boyle, Descartes, Gassendi, Grew, Hooke, Newton, Wilkins and Wallis. In addition, the three extant letters written by Molyneux to Petty make it abundantly clear that the younger man was well informed of his colleague's work on statistics,[3] and of the acrimonious debate which they occasioned on the continent. Molyneux's mathematical capabilities were of a high order, as his essays on tide-levels at Dublin, the lunar eclipse and other astronomical observations successfully demonstrate.[4] Once again the developmental pattern (experienced by Hooke, Halley, et.al.) can be detected, with the now familiar personal variations.

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1. K.T.Hoppen, Common Scientist, op.cit., especially pp.22-33, 74-76 and passim.
2. K.T.Hoppen, Common Scientist, op.cit., pp.95, 251-252, (notes 103-105).
3. B.H. MSS. 6, Section 3, letter 98, Molyneux-Petty 3 March 1682; ibid, letter 104, same to same, 6 November, 1686; ibid, letter 105, same to same, 24 May, 1687.
4. For a list of published contributions by Molyneux in the Philosophical Transactions, and continental journals cf. Hoppen, Common Scientist, op.cit., pp.222-223.

This interpretation of his attitudes is precisely illustrated in the letter written by Molyneux to Halley (as S.R.S.) on 18 April 1686.[1] As a statement of concern over the direction taken by the Royal Society, c.1683-1686, this letter crystallises the approach adopted by more perceptive English natural philosophers. Consequently, it deserves wider recognition, since it identifies those changes in motivation and procedure which many less capable figures were currently adopting. Molyneux precedes his remarks by complimenting Halley on his election as S.R.S., noting that he refrained from communicating earlier because he had 'heard of the late disturbances in the Royal Society, and was unwilling to trouble you till matters were settled'. Now that these problems had been resolved and there was a secretary who could devote all his energies to the enormous task of correspondence, and 'managing the registers with other troublesome work', Molyneux was writing in support of Halley's efforts to place the Society's affairs back on the right lines:

> 'And now, Sir, I must congratulate you upon your being settled in the place you have; I know no man more fit for it than yourself: but then as a friend you must give me leave to advice you to diligence, for truly I think you have a considerable duty to discharge ... for I found [from a previous account] there was a party arising in the Society, that were for rejecting all kinds of useful knowledge except ranking and filing of shells, insects, fishes, birds etc. under their several species and classes; and this they termed Natural History -, and Investigating Nature, never attending to the uses and properties of these things for the advantage of mankind, and reckoning chemistry, astronomy, mathematics, and mechanics, as rubs in their course after nature. This indeed seemed to me something strange; and I must confess, I could not but laugh at it ...' 2

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1. Printed Birch, History, iv, 475-479.
2. Ibid, 476.

Molyneux thereafter gives a brief report on activities in Dublin, and expounds on recent work by Hooke, Hevelius, Justel, and Huygens. He concludes the letter with some general thoughts on missile trajectories, quoting from Blondel's Art de Jetter les Bombs (Paris, 1683) and material garnered from Buot, Romer, Cassini, de la Hire and Galileo.[1]

From this letter it appears that Molyneux quickly identified the debilitating effects of undisciplined collecting, and mere antiquarianism, which were features of the changing modes of thought that threatened the creative drive of English natural philosophy. Thus eleven years before William Wotton's famous remarks, the debasement of systematic natural history was detected by at least one perceptive observer on the basis of informed scientific views, as opposed to literary and social sensibility.[2] William Petty undoubtedly concurred with Molyneux's judgment, and may well have influenced the attitudes from which it sprang, for in 1683 and 1684 he had been deeply involved with Molyneux in moulding the Dublin Philosophical Society. Although Molyneux must be regarded as the founder of this society,[3] it is clear that Petty was concerned with its organisation at an early stage.

In December 1683, after preliminary meetings where discussion wandered over the whole realm of learning, Molyneux, Petty and Willoughby formed a committee to draft rules for the better ordering of the society. This committee suggested that the institution should be called 'The

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1. For Molyneux's breadth of reference in this subject see the analysis of its general development in A.R.Hall, Ballistics in the Seventeenth Century, A Study in the Relations of Science and War with Reference Particularly to England, (reprint, New York, 1969).
2. Cf. W.Wotton: Reflections Upon Ancient and Modern Learning, (Sec. ed., London, 1697), pp.418-421.
3. K.T.Hoppen, Common Scientist, op.cit., p.23. Hoppen gives a full analysis of the immediate origins of the Society at ibid, pp.73-98.

Dublin Society for the Improving of Naturall Knowledge, Mathematicks, and Mechanics'.[1] Without giving a detailed exegesis of these regulations or the corresponding 'Oath of Obligation'[2] which accompanied them, they can be summarised as a carefully ordered exposition of the lessons inculcated by Petty's long, and frustrating experience of the Royal Society's operations. Although he now recognised obvious realities which dictated the behaviour of a voluntary society of natural philosophers, reluctantly discarding the picture of a state-endowed research institute which he had described in 1647, Petty's scheme outlined the closest viable approximation to that earlier ideal. Thus the 1684 draft rules, based on the optimal procedures of the Royal Society, demanded a vigorous and dedicated programme of research, experiment, enumeration and debate. All non-essential, discursive activities were outlawed, and the Society was to be provided with ample funds, and an efficient secretariat to organise and methodise the materials which accrued. Instrumentation, correspondence, accurate accounting: all the points on which the London Society had demonstrated inherent weakness were to be obviated by these strict regulations.

These rules immediately met with strong opposition from figures such as Loftus,[3] who objected to the rigorous exclusion of non-scientific subjects, and attacked the leading proponents from a stance close to that of Henry Stubbes. As K.T.Hoppen, (the historian of the Dublin Society) has established, the long-term development of that institution did not follow the lines recommended by Molyneux and Petty.[4]

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1. 'Rules for the Dublin Society' at B.H. MSS. 37, Box H, folder 7 (i). Printed at Petty Papers, ii, 88-90.
2. B.H. MSS. 37, Box H, folder 7, (iii).
3. K.T.Hoppen, Common Scientist, op.cit., pp.159-166; Birch, History, iv, 248, Loftus is described as 'Doctor'.
4. Ibid, p.161.

Within eleven months Petty felt the need to produce his 'Advertisements for the Dublin Society'[1] which reiterated the intentions of the original report. However, the hopes entertained by this inveterate Baconian were uncongenial to the more hap-hazard, eclectic virtuosi, who constituted the bulk of the Society's members.

With regard to Petty's attempts to regulate the operation of the Dublin Philosophical Society and the Royal Society,[2] the judgment of events proved severe and uncompromising: intellectual fashion, institutional weakness, and Petty's own inability to recognise these realities meant that his plans were doomed to failure. This is not to say that if implemented they would have proved ineffectual. On the contrary, the concepts embodied in these life-long projections were very close to those which now characterise modern research institutes. Yet here, as in so many of his ideas, Petty's failings were those which exemplify the visionary rather than the pragmatist. He was calling for developments which society and contemporary organisations were incapable of supporting, and which appeared antithetical to commonly held attitudes. Nonetheless, his role in the institutionalisation of seventeenth century science was still considerable. Petty's constant attendance at the Royal Society when in London, his dedicated concern for its proceedings, and his attempts to revive its flagging fortunes in 1674, 1680, and 1687,[3] undoubtedly helped this great seventeenth century corporate achievement to survive. These factors were widely recognised by his colleagues, and perhaps articulated most clearly by Nehemiah Grew in 1678:

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1. Dated 27 December, 1684. B.H. MSS. 37, Box H, folder 7 (ii). Printed, among other locations, at Birch History, iv, 353-354; Petty Papers, ii, 90-92; K.T.Hoppen, Common Scientist, op.cit., pp.202-203, 'Appendix B', taken from Brit. Mus. Addit. MSS. 4811. f.48v. For a copy cf. Appendix I, iii, below.
2. See below Appendix I, no.ii, for Petty's memorandum, dated 1 December, 1687, 'About ye Royall Society', which is typical of his schemes, and resembles the 'Rules for the Dublin Society'. When in the capital Petty always went to the Society's meetings, or met privately with other Fellows.
3. For plans by Petty, cf. Birch, History, iv, 6-7, 29 January, 1680; Appendix I, no.ii, below (1687); Appendix 3, i, below (1674).

'Sr,

After ye death of Mr Oldenburge, at our Anniversary Election of Officers, on St. Andrew's day; the R.Society haveing been pleased to choose me their Secretary: since then, [it] hath likewise given me order,...To acquaint these Ingenious and Learned Persons who began a Correspondance with Mr Oldenburge; yt ye continuance of ye same with me, will be very acceptable to them. Of all w^{ch}, ye first in my thoughts could be no other, but your selfe. You haveing given ye R.Society, upon all occasions, so great assurance of your mannifold Abilitys to promote their affaires. Although you may wonder, That one, who is already so much obliged to you, should presume to sollicite your further trouble. But my Addresse being in ye Name of ye Society, for whose business you have so great a love; and betwixt whome and yourself doth run so reciprocal an Honour; ye makeing of it, may seems an offence much more pardonable; than would the doubling of your compliance therewith'. 1

At this point it is appropriate to bring Petty's intellectual biography to a close. Although much more could be written about his association with other natural philosophers and friends after the Restoration, this would not affect the essential details of the outline already presented. There is, of course, a far greater stock of material relating to colleagues such as Aubrey, Pett, Wood, and Southwell[2] than has been included thus far. Some of this information will appear in subsequent pages and appendices to the current work, while other data, such as the fascinating evolution of Hooke's dispute with Sir John Cutler, and the illuminating insight which that provides into Hooke's scientific development,[3] must wait for separate treatment. Nonetheless, the skeletal structure of Petty's own development has emerged with

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1. Brit. Mus. Sloane MSS. 1942, Dr. Grew's Papers, ff.9-10. dated 20 February, 1678. For background to this and other letters to Huygens, Leibniz, Newton etc., cf. Birch, History, iii, 369.
2. A number of unpublished letters from these friends are located at B.H. MSS. 6, Sections 2 and 3; all of them show the highest regard for Petty's intellectual status.
3. MS. papers concerning this dispute, in which Petty acted as mediator, are located at B.H. MSS. Box 37, Royal Society, folder 2, (ii), all c. December 1682 - May 1683.

sufficient clarity to allow further treatment of some central themes to take place.

It is possible now to summarise Petty's evolution as a natural philosopher and major figure in seventeenth century English culture, before presenting a more detailed analysis of his ideas. Born at the beginning of one of Europe's most creative intellectual periods, Petty's early experience of English and continental developments, coupled with his outstanding ability and enormous energy, provided him with unique skills and insights that made his remarkable career first a possibility, and then a reality. In London, Oxford, Ireland, and once again in England, he vigorously pursued his ideals and personal ambitions until their material goals had been achieved. The retention of these gains diverted him from the more traditional fields of natural philosophy, yet stimulated him to investigate new avenues of thought. His apparent decline after the remarkable achievements of 1652-1660 is, in retrospect, an illusion. Although endlessly frustrated while trying to implement Baconian principles in technology, state-craft and the institutionalisation of science, his creativity in economic and sociological fields easily compensate for such failures.

While on the periphery of many central developments in English science after the Restoration, Petty never lost that brilliant perception which characterised his youth. Consequently, he wrote to Southwell, that 'As for Mr Newton's book, I would give 500£ to have been the author of it, and 200£ That Charles [Petty's son] understood it'.[1] Southwell, more circumspect and worldly-wise, counselled Petty to suppress his radical ideas on government and society, while placing them in the same category as Newton's great work:

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1. Lansdowne, P.S.C., p.279, letter to Southwell 23 July, 1687.

> 'You know Columbus made the first offer to us of his Goulden World, and was rejected; That the Sybill's Bookes, though never so true, were undervalued; and Mr Newton's demonstrations will hardly be understood. The market rule goes fair in everything else, Tantum valet quantum vendi potest. Soe as tho I doe not suspect you can be mistaken in what you assert, since you enumerate so many solid as well as bitter objections thereunto; yett the dullnesse of the world is such, the opposers soe many, your fellow labourers soe few, and your [own] Age soe advanc'd, that I reckon the worke Insuperable. However I am glad that your thoughts are all written downe, for Posterity, as favour'd by great Accidents, may cultivate what the present Age neglects ...' 1

Southwell's prescience, while brought into question by his limited scientific understanding, is remarkable in the light of recent changes in historical appreciation. For it is now reasonable to assert that Petty's later ideas place him on the same level as other leading theoreticians of this period. Long retarded by ideological hostility and the slow evolution of econometrics, an awareness is slowly emerging that his work, while lacking the clarity and elegance of Newton's great synthesis, was in itself an outstanding achievement.[2] Even Petty, in one of his more sanguine moods, sensed that this judgment was not unduly optimistic:

> '... Upon this confusion I do againe (as I have done twice already) call upon ye learned historians and antiquaries of this age to set forth

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1. Ibid, p.281, 13 August, 1687. Nehemiah Grew strongly believed, like Southwell, that 'the opposers' to natural philosophy were many, and the 'fellow labourers soe few'. Cf. Brit. Mus. Sloane MSS. 1950, Miscellaneous Papers of Nehemiah Grew, f.50v-f.51r:' The g[rea]test part of humanity is lost in earth, & yr souls so fixed in yt grosser moity of ymselves (yr bodies) yt nothing can volatilize ym & set yr reasons at liberty. You are ye enlarged & elasticall souls of ye world who removing all former rubbish, & prejudiciall resistances, do make way for ye springy intellect to fly out into its desired expansion'.
2. For this changed view of economists cf. Strauss, Sir William Petty, p.227.
G. Routh, The Origin of Economic Ideas (London, 1975), p.35, calls Petty 'the true founder of modern economics'.

> how ye severall knowne Kingdomes and cittyes were peopled in only 500 yeares since ye flood, and to set forth some hypothesis whereby to solve the Natural Phenomena of that Matter.
>
> I do also trully desire ye Many Excellent Naturalists of this age to give a Mechanicall hypothesis how ye seeds even of Vegetables (and of animalls too if it might be) do, after so many and so various changes, always terminate in producing Multitudes of ye same again; as we hope [also] from Mr Newton a deserving hypothesis whereby ye Mity Magnetics and influence of ye Stars, planets and comets will bee mechanically and mathematically exposed.
>
> Wee hope wee ourselves [have] already made such anatomyes and computations of ye lands and hands of great Brittaine and Irelande as wee do know that all ye antiquaries of this age have made or can produce for any kingdome, State or Citty of ye world at any one Epoche of some within the same [epoch and countries as Petty himself] and yet [I] complaine of lamentable defects in these performances ...' 1

Defective or not, Petty's methods and demands for the rationalisation of government anticipated by several centuries modern techniques of economic planning, statistical enumeration and sociometric analysis.

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1. B.M. MSS. 34, Box E, folder iii, 'f', final folio. This formed part of a draft copy of Two Essays in Political Arithmetic, (London, 1686). Cf. Keynes, Petty Bibliography, pp. 25-27 for details of publication.

Chapter 2

Society's Improvement:

Education, Medicine and Invention.

'To provide for poore, advance trade and make all manufactures flourish, England should bee endeavoured to bee made the shop of Europe, and it with other countries the markets. To doe this all trades and workmen should bee encouraged and all manner of compendious ways invented whereby they may come to undersel the manufactures and commodities of all other countrys. This would bee better then to strengthen their monopolizing corporations in ignorance and idlenes. Petty'

Hartlib Papers, MS. Ephemerides, 1649, C-D4.

'Let the forme of government bee what it will it matters not so much as if only the persons or governours bee holy and good. That is all in all. Id. [Petty]',

Hartlib Papers, MS. Ephemerides, 1649, B-C.4.

'If these things bee done, within ye said 9 yeares, Then ye said A.B.C. etc. will afterwards secure his M[ajes]tys Revenue in Ireland - to be worth 250m. to [£250,000] p. An. Neat [Nett] and above all Defalcations, Nor will the Charge of ye Government then need to bee 2/3 of what it must bee Now, And ye People will bee Richer by above 100, thousand-pounds p. An, without Losse to ye Said A.B.C. etc.,' B.H. MSS. 9, item 54, unfoliated, at the end of treatise endorsed 'Sir W.P.'s Proposall about the Irish Trade', copy by Sir R.Southwell.

(a) Society's Improvement:

Charles Webster's recent book has provided a comprehensive picture of the reform programme developed by Hartlib, and other puritan intellectuals, which first emerged in 1638, and re-appeared with fresh vigour in 1646. As The Great Instauration[1] has established, this movement incorporated a wide range of proposals relating to employment, education, poor relief, economic planning, agricultural reform, popularised medicine, and technological development. Its major proponents worked on various aspects of the programme in response to changing circumstances and tried to implement a large number of complimentary proposals. As they evolved, these were increasingly influenced by Bacon's scientific principles, and the general programme attracted support from a significant group of young experimental philosophers who broadly agreed with its social and economic aims.

William Petty was one of the most outstanding of these natural philosophers, and his return to England from the continent in 1646 coincided with the re-emergence of the reform campaign. His growing contact with Hartlib drew him into a web of relationships which exercised a profound influence on his attitudes and in turn allowed him to influence the character of the reform movement itself. Historically, however, there is a difficulty which complicates the description of one individual's part in this campaign: that of the precise debt and contribution of the figure concerned and the inevitable communality of ideas.[2] Thus, some of Petty's strongest principles were formulated on the basis of his acceptance of Bacon's writings, and combined with first hand knowledge of

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1. Cf. especially pp.446-464. See also B.Farrington, Francis Bacon Philosopher of Industrial Science (London, 1970), pp.1-12; J.K.Fuz, Welfare Economics in English Utopias; C.Hill, The World Turned Upside Down, Radical Ideas during the English Revolution (London, 1972) especially 70-121, 231-246; P.Zagorin, A History of Political Thought in the English Revolution, (London, 1965).
2. For a discussion of the origins of one work subject to this confusion, cf. Webster, Advancement, pp.119-120, on Considerations Tending to the Happy Accomplishment of England's Reformation (1647), which resulted from discussions between Dury and Hartlib.

Holland's more sophisticated economy. Subsequent incorporation within the reform movement only reinforced these well established attitudes. It is often difficult, or even impossible, to identify the precise origin of his ideas, or categorically state their reciprocal effect on the general programme. Given the purpose of the present chapter it is questionable whether such laboured precision would have any historical value. Instead it will be more illuminating to give a brief description of Petty's literary and personal experience, linking him with various intellectual traditions, and then show how this controlled his later activity.

The biographical material in Chapter I has established Petty's unwavering support for Baconian methodology, and his steadfast advocacy of the institutional projects and enumerative natural histories outlined in Bacon's works. As might be expected this influence was carried over into Petty's appreciation of economic and social reform. In several brilliant exercises published two years after Petty's birth, Bacon defined his attitude to economic regulation and concomitant social change:

> 'The first remedy ... is to remove by all means possible that material cause of sedition whereof we spake; which is, want and poverty in the estate. To which purpose serveth, the opening and well-balancing of trade; the cherishing of manufactures; the banishing of idleness; the repressing of waste and excess by sumptuary laws; the improvement and husbanding of the soil; the regulating of prices of things vandible; the moderating of taxes and tributes, and the like. Generally, it is to be foreseen that the population of a kingdom ... do not exceed the stock of the kingdom which should maintain them ... Therefore the multiplying of nobility ... in an over proportion to the common people, doth speedily bring a state to necessity; and so doth likewise an overgrown clergy [and too many scholars]; for they bring nothing to the stock ... [and] forasmuch as the increase of any estate must be upon the foreigner (for whatsoever is somewhere gotten is somewhere lost), there be but three things which one nation selleth unto another; the commodity as nature yieldeth it; the manufacture; and the ... carriage. So that if these three wheels go, wealth will flow as in a spring tide. And ... [often] ... the work and carriage is more worth than the material, and enrich-

> eth a state more; as is notably seen in the Low-Countrymen, who have the best mines above ground in the world'. 1

It is almost certain that Petty read Bacon's Essays when studying at Leyden in 1644-1645, where there was overwhelming evidence of the benefits of economic planning. Furthermore, in his essay on 'The True Greatness of Kingdoms and Estates', which Petty used when organising the Down Survey, Bacon underlined his wholehearted support for government regulation of socio-economic affairs:

> 'to conclude: no man can by care taking ... add a cubit to his stature, in this little model of a man's body; but in the great frame of kingdoms and commonwealths, it is in the power of princes or estates to add amplitude and greatness to their kingdoms: for by introducing such ordinances, constitutions, and customs, as we now have touched, they may sow greatness to their posterity and succession. But these things are commonly not observed, but left to take their chance'. 2

In 1646 Petty returned to an England wasted by civil war, which, through dislocation and destruction, had magnified the depressed conditions of 1620-1640. Even before his departure the country's economic infrastructure, technology and industrial development had compared poorly with Holland.[3] However, Petty soon realised that London's population, which had expanded rapidly during recent decades, was especially subject to malnutrition, disease, underemployment and general poverty.[4] When faced with this direct comparison between Leiden and London the differentials must have appeared cruel. In many cases they were unforgivable because, to Petty, they were unnecessary and could be overcome by hard work,

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1. Bacon, Works, pp.752-753, from Essays or Counsels Civil and Moral (1625 ed.), 'Essay XV. Of Seditions and Troubles'. For Petty's deliberate echo of Bacon's statements in Treatise of Taxes, cf. Hull, Economic Works, i, 23, '14. Causes of Civil War ... Wealth of the Nation is in too few men's hands ...' and Bacon, Works, p.753, 'Above all things, good policy is to be used that the treasure and monies in a state be not gathered into few hands ...'
2. Bacon, Works, p.774.
3. For example, the success of Dutch drainage engineers in Holland should be compared with their partial failure in the Fens. Cf. S.Pollard, D.W.Crossley, The Wealth of Britain, (London, 1968), p.129; L.E.Harris, Vermuyden and the Fens (London, 1953), especially pp.74-93, 118-121; H.C.Darby, The Draining of the Fens (Cambridge, 1940).
4. M.E.James, Social Problems and Policy, op.cit., pp.45-50; W.G.Brett-James, The Growth of Stuart London, (London and Middlesex Arch.Soc. 1935), especially pp.186-222.

firm governmental action, planning and technical innovation. Only by keeping these facts in mind and fully realising Petty's sensitivity to such problems, can his response to the puritan reform movement be measured. Although self-seeking, he was not without feeling. His ambition, rather than blinding him to the realities of disease and poverty, drove him to seek out those circles which could help turn his technological, social and economic visions into reality. Naturally, given his links with Pell, he investigated the group that centred on Hartlib. While largely disregarding the pietistic and moralistic approach emphasised by Hartlib and Dury,[1] Petty realised that their contacts and attitudes could provide the necessary vehicle for his talents and ambitions. Equally stimulating were the practical aspects of those schemes which multiplied and circulated in London's hot-house, reformist atmosphere.

Predictably, Hartlib's campaign greatly appealed to Petty when it stressed social pragmatism, applied science and economic planning. The immediate basis for this developing tradition stretched back through Plattes to Bacon and the early school of practical manuals.[2] In 1639 two obscure works were published in London. Plattes' Discovery of Infinite Treasure and A Discovery of Subterraneal Treasure both stressed that only systematic use of improved agricultural, industrial, mining, and metallurgical techniques, would eradicate England's economic and social problems. Above all, the introduction of new husbandry and agricultural machinery was required for 'there is no approved medicine but ... this in an overpopulated Commonwealth to wit, good improvement of the earth; which may be effected by the new inventions contained in this book [i.e. Infinite Treasure]'.[3] For Plattes a classic example of such improvement, more

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1. For example, in the Advice, Petty's comments were almost entirely secular, and only at the end (p.25) does he mention that a History of Trades would be valuable because 'Divines having so large a Booke of Gods works added to that of his word, may the more cleerely, from them both, deduce the wisedome, power and goodnesse of the Almighty'.
2. For some of these early manuals cf. L.Sharp 'Timber, Science and Economic Reform' op.cit, 52-56; a good example of such writers was Gervase Markham; cf. F.N.L.Poynter, A Bibliography of Gervase Markham (1588?-1637), (Oxford Bibliog. Soc., 1962), especially pp.29-31.
3. Plattes, A Discovery of Infinite Treasure, op.cit., Epistle Dedicatory.

valuable than 'all the Hospitalls in England', was 'the fertilizing of Land with Lime or Marle' which enabled 'an infinite number both to feed and clothe themselves and others ...' Two years later Plattes wrote a seminal work called A Description of the Famous Kingdom of Macaria[1] (1641) which was dedicated to Parliament and demanded the reorganisation of government, education the church and popular medical services. With five councils to encourage the improvement of national trade, fishing, husbandry, and plantations, and a Grand Council to direct and control these subsidiary bodies, this essay was published by Hartlib as a contribution to the debate over political reform. Couched in Baconian terms,[2] and promising the creation of national wealth at an unprecedented rate, these proposals were, unfortunately, nullified by the onset of civil war.

In 1647 their spirit was revived by Hartlib and Dury and promulgated in a new scheme for two Offices of Address. This project, first publicised in Englands Reformation (1647),[3] was also viewed as a serious contribution to the ongoing debate over national reform, and was therefore dedicated to Parliament like Macaria had been six years before. Once again, fundamental reorganisation of England's socio-economic affairs was envisaged, in the confident expectation that this would inevitably create a more equitable and productive society:

> 'And although the maintaining of these Offices of Addresse in one respect may be commended to the State, as the greatest Worke of Charity, which can bee bestowed upon the whole Nation ... yet ... the Charges ... will bee found the most profitable and richest Trade that they can drive, to increase their owne worldly Substance: for it will direct them both to preserve without losse, and mannage all that they have within the Kingdome to the

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1. Cf. C.Webster, 'Authorship and significance of Macaria', op.cit.
2. [Plattes], Macaria, op.cit., p.9, quotes More's Utopia and Bacon's New Atlantis, as early utopian visions, but claims that Macaria is a more practical blue-print for social and economic reform.
3. [Dury and Hartlib], Englands Reformation, in Webster, Advancement, pp. 120-139. See also C.Webster, 'Samuel Hartlib and the Great Reformation' Acta Comeniana, 26 (1970), 147-164.

> best advantage, and also to increase their Stock every way by all the Negotiations which are afoot amongst their subjects, within themselves, or towards their Neighbour Nations'. [1]

The reformers intended the two offices to perform very different functions. The first, called the 'Addresse of Accomodations',[2] was designed to organise, develop and regulate all areas of economic and social behaviour. Using a national system of bureaux it would collect all types of data, acting as an employment exchange, land register and commodity exchange, regulator of production, trade and coinage, an estate agency, census office, registry of births, marriages and deaths, and a central source of information on which economic planning by the government could be based. The 'Office of Addresse for Communications',[3] on the other hand, was concerned primarily with establishing a basis for religious agreement, and then with implementing a joint programme to spread methods derived from Bacon's 'De Augmentis Scientiarium amongst the Learned', and Comenian ideas on education throughout England's schools. Finally, the 'Office of Communications' was to be 'made a Center and Meeting-place of Advices, of Proposalls, of Treaties and of all Manner of Intellectual Rarities freely to be given and received ...' This research and development was to be organised 'according to the Counsell and Designe of the Lord Verulam'.

Although Hartlib's Office of Address was given official sanction it never received effective state support. He therefore tried to perform some of its functions, acting as intelligencer, co-ordinator, publisher, and patron, to a succession of inventors, educationalists, natural philosophers, and authors of miscellaneous tracts on reform. As the years passed there was a detectable shift on his part away from his earlier pietism towards

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1. Ibid, p.135.
2. Ibid, pp.126-129. This controversial institution received more detailed description in A further Discoverie of the Office of Publick Addresse for Accomodations (London, 1648), which was a product of the communal debate among reformers.
3. Webster, Advancement, pp.131-135. Quotations from pp.132, 134.

belief in, and support for, the development and dissemination of new agricultural and industrial technology. Increasingly, the word 'Improvement' became the movement's talisman. Thus, Hartlib noted in 1650 that:

> 'Dr. Child can not conceive how much more the husbandry of most graine in England can bee more improved then it is already, except the commons in England which are pretended for the good of the poore but makes them live basely, poorly and idly, whereas they might bee hugely improoved. But if the land were put all into gardening and enclosures it would maintaine twice as many people as now it doth'. 1

If society could not be transformed by revolutionary[2] changes in government and education, it could at least be 'improved' by state economic control and rapid dissemination of new technology, much of which came from Holland and Germany.[3]

As a result of such efforts, a distinct tradition of 'improvement literature' developed in mid-seventeenth century England. Thus, Weston's Discourse of Husbandrie used in Brabant and Flanders; shewing the wonderfull improvement of Land there, (London, 1650), was preceded by Blith's English Improver : Or a New Survey of Husbandry (London, 1649) and followed by two further editions of Blith's work entitled The English Improver

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1. Hartlib Papers, MS. Ephemerides, 1650, G-H4.
2. This shift accompanied declining belief in chiliasm and millenarianism. For Hartlib's increasing interest in technology, cf. Hartlib Papers, viii, 60, f.1, 'Catalogus Inventorum' and Ibid., 10, f.1, on pumps.
3. This subject demands further research. However, cf. C.Wilson 'Cloth Production and International Competition ...' op.cit., p.96; G.E. Fussell, 'Low Countries' Influence on England Farming', Eng.Hist. Rev., 74 (1959), 611-622; H.W.Dickinson and A.A.Gomme, 'Netherlands contribution to Gt. Britain's engineering and technology to the year 1700' Archives Internationales d'Histoire des Sciences, xxix, 11, (1950), 356-377; G.Doorman, Patents for Inventions in the Netherlands [1500-1800], trans., J.Heijer (The Hague, 1942), pp.39-80. For later exchanges of technology, cf. P.Mathias 'Skills and the Diffusion of Innovations from Britain in the Eighteenth Century' Trans. Roy. Hist. Soc., 25 (Fifth Series, 1975), 93-113.

Improv'd (London, 1652, 1653). A flood of agricultural manuals, including three editions of Samuel Hartlib His Legacie,[1] Taylor's Common-Good : or the Improvement of Commons, Forrests, and Chases, by Inclosure, (London, 1652) and Shaw's Certaine plaine and easie Demonstrations (London, 1657) built up this tradition. Furthermore, contemporaries (and more recently, some historians)[2] stressed that there were real benefits to be gained from intelligent use of such manuals, especially those written by Blith.

Despite a short period of quiescence,[3] this tradition reappeared after the Restoration. Although there were marked changes in emphasis, especially over commercial profit as opposed to social reform, books like John Smith's England's Improvement Revived (1670, 1673), Andrew Yarranton's England's Improvement by Sea and Land (1677, 1681), Carew Reynell's True English Interest : Or an Account of the Chief National Improvements (1674), Roger Coke's England's Improvement (1675) and John Houghton's A Collection of Letters for the Improvement of Husbandry and Trade[4] all

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1. Based on Weston's Discourse, this agricultural manual expanded with each edition (1651, 1652, 1655) and embodied many of Hartlib's later interests. See also S.Hartlib, The Reformed Husbandman (London, 1651); [Cressey Dymock], An Invention of Engines of Motion (London, 1651), dedicated to Hartlib; Hartlib Papers, lxxi, a box entitled 'Miscellaneous papers relating to Inventions ... [1633-1661] ...'
2. Pollard, Crossley, Wealth of Britain, op.cit., pp.126-131; J.Thirsk, 'New Crops and their diffusion' in, ed., C.W.Chalkin, M.A.Havinden, Rural Change and Urban Growth, 1500-1800, (London, 1975) p.98, on the accuracy of Blith's figures. See Hartlib Papers, xxvi, 35, f.1, letter from the Vicar of Downton, (a friend of Dymock) dated 31 August, 1652, noting successful use of 'Blyth's' book and requesting further information on various techniques. For another letter, dated 26 July, 1658, from 'W.B.' to Dymock, discussing Blith's books cf. ibid, lxvi, 23, ff.1-2.
3. For further background information cf. L.Sharp 'Timber, Science and Economic Reform' op.cit., 59-63.
4. Houghton also published England's Great Happiness ... [showing] that a great part of our complaints are causeless. And we have more Wealth now, than ever we had at any time since the Restauration ... (London, 1677). This carried the same message as Petty's Political Arithmetick.

advocated state regulation of the economy, systematic development of England's resources, new methods of transport and communication, and the introduction of new technologies to increase agricultural and industrial productivity.

This literary tradition, so obviously associated with Baconian predications, also appealed to many figures involved with the Royal Society. Thus Hooke met Yarranton to discuss foreign metallurgical techniques.[1] Oldenburg lavished space in the Philosophical Transactions on reviewing on reviewing and listing improvement literature, which was classified under the general heading of 'the growth of Ingenuous Arts ...'[2] Evelyn assiduously collected books belonging to this tradition which, along with works on the mechanical trades, were categorised in 1687 as 'Historiae Materiarum et OEconom: Rei Rustici Mechanologici, Etc. ...'[3] In addition, his Sylva should be regarded as a synthesis of the tradition's views on timber-planting.[4] In the Classified Papers of the Royal Society there is also a short, but valuable study of the genre entitled 'MR Reason Melish his discourse concerning the best way of England's Improvement', which surveys common ideas on economic regulation and systematic increase of wealth through new technology and enhanced productivity. The concepts embodied in Melish's tract were echoed, twenty

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1. Ed. Robinson and Adams, Diary of Robert Hooke, op.cit., pp.76-7, 247, 249, 252, 308, 310; Hooke also met Smith; cf.pp.91 and 117. See also J.R.Jacob 'Restoration, Reformation and the Origins of the Royal Society', Hist. Sci., xiii (1975), 155-176, especially 170-171.
2. See Philosophical Transactions, ci (25 March, 1674) 19-20, Oldenburg's comments on improvement and reviews of works by Fortrey and L'Estrange; ibid, cii (27 April, 1674) 38-40, reviews of Reynel, Smith; ibid, ciii (25 May, 1674), 55-59, further review of Smith; ibid, cxi (22 February, 1675) 252, review of R.Haines, The Prevention of Poverty; ibid, Dedicatory Epistle to volume 10 (1675-1676) extended comments on improvement and 'the growth of Ingenuous Arts'; ibid, cxiii, (26 April, 1675), 293-296, 'The Improvement of Cornwall by Sea-Sand'; ibid, cxiv (24 May, 1675), passim; ibid, cxxi (24 January, 1676), 512, review of Coke; ibid, cxxxi (29 January, 1677), 795-798, review of Yarranton.
3. G.L.Keynes, John Evelyn : A Study in Bibliophily and Bibliography of his Writings, (2nd. ed., Oxford, 1968), pp.297-303.
4. Cf. L.Sharp, 'Timber, Science and Economic Reform', op.cit., 63-68.

years later, in notes by Samuel Pepys.[1] Finally, there is Grew's superb treatise entitled 'The Meanes of a most Ample Encrease of the Wealth and Strength of England, In a Few Years, Humbly Represented to Her Majestie [Anne] In the 5th Year of Her Reign'.[2] Dating from 1702, this substantial work on economic improvement was both a masterful summary, and a convincing expression of this important English tradition of economic reform.

Although it is difficult to assess the practical effects of this literary genre, there can be no doubt that it articulated widely held beliefs about England's potential for economic growth and successful competition with Holland and France. Despite wide variance in their detailed recommendations, and the fact that such ideas were not restricted to England alone (as Packe's translation of Glauber shows),[3] these works exhibit certain common idiosyncracies which help to establish them as a specialised, and peculiarly English, school of economic thought. Common to all of them is an accent on the need for strong governmental action to raise productivity through organised research and the dissemination of new techniques among every social class. In addition, while many of them wanted the government to restrain certain imports, they usually argued for unrestricted and expansionist trade in finished goods, and the encouragement of immigration by foreign craftsmen[4] to bring in skills and advanced technology from France, Holland and Germany.

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1. Royal Society, Classified Papers, X, (3), 16. For Pepys' 'Works of Publick Utility ...' [1702] cf. Private Correspondence of Samuel Pepys, 1679-1703, (London, 1926), ii, 294.
2. Brit. Mus. Lansdowne MS. 691; described in: E.A.Johnson 'Nehemiah Grew: A Forgotten Mercantilist' Amer. Econ. Rev., 21 (1931), 462-480; L.Sharp 'Timber', op.cit., 71-73.
3. Ed. C.Packe, The Works of the Highly Experienced and Famous Chymist, John Rudolph Glauber (London, 1679), pp.295 et seq, The Prosperity of Germany (written c.1648-1655), where Glauber argues that, after the Thirty Years' War, Germany needed systematic improvement in agricultural, industrial and mining technology.
4. As did Petty. Cf. Hull, Economic Works, i, 262. For similar statements on immigration, and the balance of trade, cf. H.Robinson, Certain Proposalls In order to the Peoples Freedom and Accomodation (London, 1652), pp.12-18.

Petty's attitude to economic theory, technical innovation, education and general socio-economic development can be placed unequivocally within this tradition. Although he later applied mathematical techniques to these ideas, and almost single-handedly pursued the enumerative concepts embodied in the Office of Address, his basic approach was founded on this common heritage. The quotation from Hartlib's Ephemerides (1649) which prefaces this chapter gives a good example of his basic pre-suppositions. A year earlier, Petty expressed these opinions publicly in the Advice, when discussing the economic effect of the History of Trades and technical innovation:

> '11. We see that all Countries where Manufactures and Trades flourish, as Holland, etc., become potent and rich. For how can it otherwise be? When the Revenues of the State shall be encreased by new and more Customes, all Beggers feeding upon the Labours of other men, and even Theeves and Robbers (made for want of better employment) shall be set on work, barren grounds made fruitfull, wet dry, and dry wet, when even hogs and more indocile beasts shall be taught to labour, when all vile Materials shall be turned to Noble uses, when one man or horse shall do as much as three, and everything improved to strange Advantages'. 1

Throughout Petty's career this fundamental concern for systematic expansion of the nation's wealth, and a corresponding improvement in general standards of living and health-care, dictated the course which his theories and activities were to follow. Uncompromisingly radical, he called for an end to corrupt governmental practice, liberal rules on the freedom of conscience, equitable increases in taxation, and the reorganisation of educational, medical, clerical, and legal services according to social need rather than historical accident. Such changes, he argued, would create greater social tranquility, economic integration and productive efficiency.[2]

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1. Petty, Advice, pp.22-23.
2. Ideas first mooted in Advice, p.23, number 12; given more extensive treatment in Treatise of Taxes, cf. Hull, Economic Works, i, 21-37.

Always a believer in democracy rather than elitism, Petty tried, in 1649, to introduce the technical means whereby wider enfranchisement would become a reality.[1] Thirteen years later, in the Treatise of Taxes, he again hinted strongly at a belief in universal suffrage. These political views may have been influenced by his early study of Suarez when at the seminary in Caen.[2] The outstanding, unchanging aspects of Petty's political and social proposals were their unsentimental radicalism, and their support for any measure which could improve industrial productivity and social harmony. They relied on the assumption that only consistent application of empirical and enumerative planning and regulation would foster England's full and undoubted potential.

Perhaps the most succinct expression of these beliefs occurred in the first chapter of Political Arithmetick, whose title crystallised the spirit underlying Petty's theoretical standpoint:

> 'That a small Country and few People by its Situation, Trade, and Policy, may be equivalent in Wealth and Strength, to a far greater People and Territory: And particularly that conveniences for Shipping and Water Carriage, do most Eminently and Fundamentally conduce thereunto'. 3

Echoing Bacon's dicta of fifty years before, and many proposals for economic innovation and regulation from the 1640s and 1650s, this brilliant exercise gave a singularly lucid account of England's potential for improvement.[4] Naturally enough, Petty quoted Holland as the best example

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1. Hartlib Papers, MS. Ephemerides, 1649, B-C3/B-C4.
2. Hull, Economic Works, i, 23, number 13. For this important early influence on Petty's economic and political views, cf. R.Wilenius, Social and Political Theory of Suarez, op.cit., especially pp.69-74, 82-95. See also Petty Papers, i, 12, 'Memorandum (i)'; Zagorin, Political Thought, op.cit., pp.23-25, 144-145, for comparison with the ideas of Overton and Harrington.
3. Hull, Economic Works, i, 249-268.
4. It should be compared with Temple's Observations Upon the United Provinces of the Netherlands, (London, 1673) ed., Sir G.Clark (Oxford, 1972), pp.5-6, 108-126; also with Henry Robinson's succinct observations in Certain Proposalls, op.cit., pp.8-11. On Robinson cf. W.K.Jordan, Men of Substance (Chicago, Cambridge, 1942) especially pp.215-258.

of an 'improved' society, with its advanced economic institutions and outstanding industrial capacity. Holland was in turn compared with France, whose greater size, Petty argued, was easily outweighed by the concentrated effiency of its diminutive neighbour. Using the most accurate statistical data available Petty analysed the revenues, capital assets, wealth distribution, gross national product and interest rates in each country. From this comparative data, Petty concluded that:

> 'upon the whole it seems, that though France be in People to Holland and Zealand as 13 to 1, and in quantity of good Land, as 80 to one, yet it is not 13 times richer and stronger, much less 80 times, nor much above thrice, which was to be proved'. 1

The cause of this disparity was due to the 'Situation, Trade and Policy of the places respectively'. Holland's cheap, and universally available water transport, wind-powered machinery, location at the mouth of three great rivers, higher agricultural productivity, domination of international bulk transport, enormous fishing industry, religious freedom, sophisticated systems for banking, trading and exchange, encouragement of immigration, specialised manufacturing industries and pragmatic governmental policy, provided a series of accumulating benefits that became economically self-perpetuating.

> 'From hence it necessarily follows, that this People must Labour hard, and set all hands to Work: Rich and Poor, Young and Old, must study the Art of Number, Weight and Measure; must fare hard, provide for Impotents, and for Orphans, out of hope to make profit by their Labours: must punish the Lazy by Labour, and not by cripling them: I say, all these particulars, said to be the subtile excogitations of the Hollanders, seem to me, but what could not almost have been otherwise.
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> Liberty of Conscience, Registry of Conveyances, small Customs, Banks, Lumbards, and Law Merchants, rise all from the same Spring, and tend to the Same Sea; as for lowness of Interest, it is also a necessary effect of all the premisses, and not the Fruit of their contrivance'. 2

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1. Hull, Economic Works, i, 254-255; cf. also Lansdowne, Petty Papers, ii, 185-6, 'Holland'.
2. Ibid, p.261. For one aspect of Dutch sea-carrying domination, cf. F.J. Bowman, 'Dutch Diplomacy and the Baltic Grain Trade, 1600-1660', Pacific Hist. Rev 5 (1936), 337-343.

It was Petty's profound hope that he could persuade the English government to encourage such developments. Once again the central paradox of his life is highlighted in that his stress on comprehensive governmental regulation, allied with economic and technological pragmatism, was unrealistic in post-Restoration England.

However, if Petty was unable to influence public affairs, he could at least try to implement his beliefs on a private level. His accumulation of personal wealth and extensive Irish estates provided the opportunity for him to put these ideas into practice. He often said of Ireland that, since it was so undeveloped and held great economic potential, it provided the best, and certainly the least complex, location for socio-economic experiments.[1] It was from this point of view that Petty fostered his 'industrial colony' in Kerry and, when describing his activities in a letter to Arthur Annesley, Earl of Anglesey, in December 1672, he said that his aim was:

> '... lastly (I thanke God) to provide employm^t for 300 usefull Artisans and Labourers, without proffitt to My Self. The last sort are Politicall Arithmetick [and] The Politicall Anattomy of Ireland. Whereupon I thinke depends the Politicall Medicine of that Country, And these Things I doe w^thout passion or Interest faction or party, but as I thinke [are] according to ye Aeternall Lawes & measures of Truth'. [2]

It has already been noted that the Kerry project was a considerable thorn in Petty's flesh, and its demise during the rebellion of 1687 seems to confirm the view that after such a troublesome existence, its eventual failure was predictable. This interpretation would not, however, be judicious, simply because it was a remarkable achievement for anyone to

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1. See his comments in Treatise of Taxes, in Hull, Economic Works, i, 9; in Political Anatomy of Ireland, (1672), at ibid, 214-220, 'Considerations relating to the Improvement of Ireland'; Petty Papers, i, 108, 'an experiment may be better tryed upon poor Ireland than ... proud England'.
2. Letter dated 17 December, 1672, at B.H. MSS. Volume 19, pp.103-104. This volume of letters provides extensive information on the Kerry colony, and includes Petty's long and impassioned correspondence with his various agents. Further information is also in Volumes 13-18.

establish a colony in such an isolated and inhospitable region. The fact that this (by Irish standards) large and complex industrial undertaking managed to survive, and at times even prosper, despite hostile conditions, was a further notable achievement. In fact, during its twenty-two years the colony exported large quantities of salted fish, a broad range of timber products (including pipe-staves), thousands of tons of bar-iron, some lead and copper, marble for building, and limited amounts of beef, tanned leather, wool and possibly charcoal.[1] To produce these goods a large complex of dams, mills, furnaces, forges, storage sheds, domestic buildings, wharves and sea defences were built.[2] The widest range of technological skills were initially required to design, construct and organise the colony. Although Petty imported (at great cost) large numbers of skilled workmen to run its industrial processes,[3] there can be no doubt that he had mastered both theoretical and practical aspects of the crafts that were involved.[4] These included smelting, smithing, pumping and water works, charcoal making, building, fishing, food preservation, forestry, mining, and navigation. He also had an acute understanding of the basic mathematics employed in calculating production yields, transport costs, exchange rates, container sizes, and general book-keeping.[5]

Although Petty hoped to make money, he also wished to improve the two nations by exploiting natural resources, creating new industries, stimulating trade and giving work to the people. Undeniable proof of his sincerity

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1. Cf. B.H. MSS. Volume 14, p.5, letter Rutter to Petty, dated 13 August, 1672, for a clear description of iron-making in Kerry, and B.H. MSS. Volume 16, pp.58-59, letter Waller to Petty, 8 November, 1673, describing fish-production, smelting etc. For a brief discussion of the extent of other Irish industrial undertakings cf. E.McCracken The Irish Woods since Tudor Times (Newton Abbot, 1971), pp.57-96.
2. For a description of such installations cf. H.R.Schubert, History of the British Iron and Steel Industry [c.450 B.C.-1775.A.D.], (London, 1957), pp.157-291.
3. Cf. B.H. MSS. Volume 8, item 87, complaints about mismanagement of the iron works, with a list appended: 'The Workemens names and qualifications, brought to Glanerought most of them at Sir. Wm's Charge ...'
4. See chapter,3Section 'e', below.
5. For these skills cf. B.H. MSS. Volume 19, pp.45, 48, 66, 148-149, 278, passim.

can be drawn from the fact that he poured thousands of pounds into Kerry between 1663 and 1675, for very little financial return. Furthermore, though this colony was never structured along the advanced lines of his 'Proposall Concerning American Plantations',[1] it was a working model for further experiments. Despite ultimate failure, there was no intrinsic reason why it could not succeed. On the contrary, extrinsic factors such as Petty's extended absence, the effects of deleterious legislation, the physical shortage of money and inadequate facilities for trading, exchange and credit, limited its success and capacity for growth.

Thus, there can be no question about Petty's support for the English tradition which called for socio-economic change to 'improve' society. These commonly held beliefs provided the foundation on which all his ideas and projects were ultimately based. Although his appreciation of how this improvement should be judged and implemented, changed as he took an increasingly mathematical view of economic and social phenomena, its final purpose never altered. The thread of continuity unravelled in an unbroken line from his early years in Holland to the final days in London. To show the validity of this interpretation and illustrate the subtle shift that occurred in Petty's attitudes, it is necessary to investigate three subjects on which he made important pronouncements early on, and which continued to absorb him, in their different fashions, until his death. Keeping in mind his cri de coeur of 1673, this investigation will concentrate less on the historical background to these interests, and more on the evolution of his own ideas:

> 'The want daily [caused by a] decrease of Mony is such here as Will I verily beleive necessitate some Application from hence & into England for restoring the Cattle Trade, & that I suppose will occasion some allowed Meetings or Addresses, And if so, I shall God willing try again whether Men will

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1. Lansdowne, Petty Papers, ii, 119-120. Petty also drew up advanced theoretical plans for Irish plantation colonies. Cf. B.H. MSS. 34, Box E, folder 1, k, 'Irish Colony', which discusses free medical care, housing, education, etc.

> see their Interest through my Optiques (wch they seldome hitherto have don directly, though very often by Reflection) ...' 1

(b) Education:

With a man so devoted to self interest it might appear anomalous that, for over twenty-five years, Petty supported two schools in his home town of Romsey. This enduring philanthropy was due to genuine concern for the underprivileged. As the schools' trustees ingenuously remarked,

> '[it] is the burthen of your care, that youth may be ingeneously educated in good literature, and the poore releeved with ye fruits of your noble bounty'. 2

This involvement with his own parish reflects Petty's life-long concern for the reform of England's educational system. Although his major comments on the subject appeared in The Advice to Samuel Hartlib for the Advancement of some particular Parts of Learning, (1648), Petty wrote numerous short essays, notes and letters on education throughout his career.

The Advice was composed as Petty's private contribution to the educative portion of Hartlib's programme for social reform. While this pamphlet shared many common features with works by Lodwick, Kinner, Woodward, Pell, Comenius, Dury, Hartlib and Bacon,[3] deliberately referring to three of these seven major figures, it was still a highly personal statement:

> 'Intending onely to shew where our owne shoe pincheth us, or to point at some process of Knowledge, the improvement whereof (as we at least conceive) would make much to the [g]enerall good and comfort of mankind'. 4

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1. B.H. MSS. Volume 19, p.163, letter dated 22 March, 1673, to Lady Ranelagh
2. B.H. MSS. Volume 6, Section ii, letter dated Romsey, 13 May, 1671. Other letters from Petty to the vicar, and from the trustees, (c.1674 and 1685) are at ibid, section ii, 19 and 32.
3. For references to Bacon see Advice, pp.1, 26; for Pell, pp.7, 17; for Hartlib see title page, dedicatory letter, and pp.1 and 2, where Petty refers to him as the 'Master-Builder'. For the general background cf. Webster, Advancement, pp.39-60; idem, Instauration, Chapter 3; T.H.H. Rae, John Dury, op.cit., passim.
4. Ibid, p.1.

Although idiosyncratic, it was also designed to fit Hartlib's general schema, and to amplify certain parts of Bacon's Advancement of Learning, which had already provided an exemplary 'Definition or nice Division'[1] of the subject. This placement explains the pamphlet's reference to Petty's writing invention, the History of Trades, economic improvement, Baconian natural history, and the Office of Address: elements of the Advice which have received attention in preceding sections of this thesis.

The strictly educational aspects of the treatise can be divided into two generically distinct sections: that relating to the education of children and youths, and the separate description of a model training hospital or 'Nosecomium Academicum'. Petty's 'flying thoughts, concerning the Advancement of Reall Learning ... particularly ... the Education of Youth, Mathematicks, Mechanicks, Physick and the History of Art and Nature' were designed to appeal to a limited, yet discerning audience, and relied on several basic assumptions. Firstly, there was the universal right of children to equality of educational opportunity. Secondly, there was the enormous potential that correct educational methods possessed to further social change and economic improvement. Thirdly, he saw the need for experimental and technical training along Baconian lines.

In the Advice Petty demanded that a national system of schools, called 'Ergastula Literaria', should be created.[2] Like Hezekiah Woodward, he stipulated that these 'Literary work-houses', should employ well paid, skilled and dedicated schoolmasters, instead of those dull incompetents who were the current norm.[3] All children over seven, rich or poor, would receive their early education at these institutions, and

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1. Ibid.
2. Ibid, description of the schools, pp.3-7.
3. For a brief account of Woodward cf. C.B.Freeman, 'A Puritan Educator: Hezekiah Woodward and his "Childes Patrimony"', Brit.J.Educ.Studies, 9 (1960), 132-142, especially 136, for Woodward on the low quality of teachers.

> 'none [shall be] excluded by reason of the poverty and unability of their Parents, for hereby it hath come to passe that many are now holding the Plough, which might have beene made fit to steere the State'. 1

The poor children would be expected to work in order to pay for their tuition, and wealthier children would benefit enormously from innovatory elements in the curriculum.

Following the dictates of Bacon, Comenius, Woodward and Kinner,[2] Petty suggested that language teaching should be conducted in the vernacular, beginning with simple objects, and building from this towards a complex syntactical understanding. New reading techniques should be introduced and accompanied by tuition in new methods of writing and shorthand. In particular, Petty referred to the use of 'Reall Characters',[3] a type of artificial alphabet and language which directly represented objects and articles with the minimum number of individual symbols. This suggestion reflected Petty's own 'Hobbesian' obsession with ambiguosity and definition and the more immediate influence of Francis Lodwick.[4] This talented merchant's understanding of international communication led him to develop new linguistic systems, and their friendship reinforced Petty's own attempts to produce a symbolic notation for botanical terminology and nomenclature.[5] By learning a new language which directly represented objects in terms of their size, shape and other perceptible characteristics,

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1. Petty, Advice, p.4. The phrase about 'holding the Plough' is reminiscent of Plattes' comment, Discovery of Infinite Treasure, op.cit., (Dedicatory Epistle) Sig.a, 'the reasons hereafter declared are sufficient to turne Plow-men into Philosophers'. Plattes also called for a 'College for Inventions in Husbandrie', ibid, p.72.
2. For a discussion of these influences cf. V.Salmon, The Works of Francis Lodwick, op.cit., especially pp.76-79 for Bacon's early, stimulating work. For Kinner's A Continuation of ... Comenius, which Petty translated c.1647-8, see above p. 75 , and A Continuation Sig A.3.r, pp.1-6, for Kinner on the natural way to teach languages, which deeply influenced Petty.
3. Advice, pp.4-5, for Petty's views on language teaching, and 21, 23 for his condemnation of grammar school procedures.
4. See Anon [but F.Lodwick] A Common Writing, (London, 1647) and Salmon, op.cit., especially pp.53-58, 80-81 on Lodwick and Petty.
5. For Petty's critical discussion of 'Champagnolla's Characters', another universal language system, cf. Hartlib Papers, MS. Ephemerides, 1650, F-G.8.

children's minds would be drawn to the empirical study of nature. In addition to reading and writing, the students should also receive simplified instruction in the arts of 'Artificiall Memory',[1] in 'Elements of Arithmetick and Geometry' (because of their utilitarian value), and in music, draughtsmanship and languages according to the dictates of individual talent or intended career.

Of equal importance to Petty was the need for vocational and technical training, which utilised his projected History of Trades. He demanded that 'all Children, though of the highest rank, be taught some gentile Manufacture in their minority'.[2] This would help the under-privileged to choose a trade, introducing them to its basic techniques and reducing their period of training. For the upper classes it would provide valuable instruction, encouraging some to invest in technology and experimental science, and enabling all to spend their time and money wisely, avoiding the cheats of tradesmen and the snares of idleness. This technical education was the most natural, and certainly, in terms of national improvement, the most productive innovation. Above all it matched the psychological stages of cognitive development which all children inevitably experience:

> '[as] it would be more profitable to Boyes, to spend ten or twelve years in the Study of Things, and of this Book of Faculties, then in a rabble of words, so it would be more easie and pleasant to them, as more suitable to the naturall propensions we observe in them ... By all which it is most evident that Children do most naturally delight in things, and are most capable of learning them, having quick Sences to receive them and unpreoccupied memories to retaine them'. 3

Finally, every child was to take regular exercise and to witness at first-hand the results of licentiousness, crime and inebriation, thereby en-

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1. For Petty on better teaching methods for musical notation, using 'Artificiall Memory' cf. ibid, 1648, N-0.6-7.
2. Advice, pp.5-6. The trades included instrument making, optical work, industrial chemistry, anatomy, dialling, nautical mechanics etc.
3. Ibid. p.21.

encouraging an innate appreciation of moral virtue.[1]

Hartlib circulated copies of the Advice among numerous friends and acquaintances.[2] As a result, Petty's radical attitudes probably stimulated William Sprigg to attack the value of universal education in A Modest Plea for an Equal Common-wealth (London, 1659),[3] which pointed out that this could only create legions of overtrained, dissatisfied and unemployed youths who would threaten the established social order. On the other hand, William Dell's Tryall of Spirits[4] may have been influenced by the Advice in its advocation of a national system of training schools and colleges. More immediately, George Snell may have absorbed some of Petty's ideas and, having emasculated those which encouraged social mobility (like Dury and Hartlib in England's Reformation),[5] incorporated many others in The Right Teaching of Useful Knowledg[e] to fit Scholars for some honest Profession ... (London, 1649).[6] However, the most direct response to Petty's treatise was provided by two of Hartlib's acquaintants. The first was Symner, who wrote to Sir Robert King on 24 October, 1648 that:

> 'I had ye happiness to have a Lettr of late from yu & wth it MR. W.P. his Advice for ye Advancem^{t} of Learning And for both doe most humbly thank yu & doe most heartily wish, yt [as] with my Ld Verulam & some others have wished before me, yt at the least an Office of Intelligence might be set up, for those R[eason]s in MR. W.P. his Booke & some others, sith wee may rather wish than hope for ye foundation and maintenance of such a Colledge as hee speakes off'. 7

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1. This brutal type of moral education was one of Petty's favourite themes. Cf. Advice p.5, and Hartlib Papers. MS. Ephemerides, 1650 G-H5. No doubt, as a doctor, he saw the results of moral turpitude, though this did not stop him from siring an illegitimate daughter later on in life.
2. Thus he sent the tract to Boyle on the 16 November, 1647. Cf. Boyle, Works (1772 ed.) vi, 76. Twelve years later he sent a copy to Winthrop cf. note in Hartlib Papers, xxxii, 1, f.12r.
3. For Spriggs rejection of equality of education cf. A Modest Plea, op.cit. pp.49-55.
4. Published London, 1653; for his absorption of Petty's ideas see section entitled 'The Secular Testimony of Martin Luther ...', pp.25-30, subtitle, 'The Right Reformation of Learning'. Both Dell and Webster were also responding to wider sources.
5. Cf. Webster, Advancement, p.123.
6. Snell, op.cit., pp.52-54, 86-94, 115, 214-215.
7. Brit.Mus.Sloane MSS. 427 f.85. Another copy at Hartlib Papers, xlvii, 6, f.1.

The second, more extended commentary accepted the radical intentions, (education and social) underlying Petty's tract, but made a series of observations on the practicality of its detailed proposals.[1] If willing supporters could be gathered, then it would cost about £2,000 to initiate the most important projects such as the survey of experimental and mechanical learning, the Office of Address and the Nosecomium Academicum. The Gymnasium Mechanicum would cost at least £2,000 or £3,000 per annum, so it was suggested that individuals should be encouraged to compete for official parliamentary recognition as the national master of each trade, and these master craftsmen should then form a 'Society or Corporation for the Advancement of Arts and Manufactures'. This short anonymous manuscript is perhaps one of the most illuminating and cogent pieces of criticism to come out of the educational reform programme, and it is significant that its author whole-heartedly agreed with the radical attitudes underlying Petty's proposals.

In addition to the Advice, the young Baconian reformer made several important, but unpublished, contributions to the ongoing debate during 1648 and 1649. Among these comments the most significant were the 'Q[estion] and Desiderata of. [the] O[ffice] of Addresse', a draft for 'A memoriall for [the] advancement of Universall Learning', and some penetrating observations on the current state of Gresham College and its pressing need for reform.[2] As might be expected these proposals share many common features which illustrate Petty's attitude to education, the Office of Address, and the various agencies suggested by Hartlib. They are all couched in terse and factual language, exhibit a disregard for accepted social and institutional convention, and lay heavy emphasis on utilitarian, technological and mercantile aspects of the advancement of learning. Although doubt may be thrown on the authorship of 'A Memoriall

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1. Cf. Appendix 2, ii, 'A Remonstrance of the feasability of the Designes described by W.P. in his Advices to MR. Samuel Hartlib ...'
2. Cf. Appendix 2, item i, and Webster, Instauration, pp.551-553, Appendix viii, 'Memorial for Universal Learning'; pp.548-551, Appendix vii, 'Gresham College'; pp.51-53, 221-223, 365-366.

...' in that this anonymous document probably summarised the results of common debate, there can be no question that (as its first paragraph indicates) Petty's influence was strongly felt.

The earliest of these three critiques was probably that commenting on the Office of Address. As the Advice[1] illustrates, Petty was deeply impressed by the proposals in England's Reformation. It is therefore likely that Hartlib encouraged his young protegee to write an appraisal of the Office of Address, and, as the reference in paragraph one to his work entitled 'Vellus Aureum ...' makes clear, Petty obliged with some precise suggestions. Reflecting the common demand for regulation and exegesis of international trade, exemplified by The Merchants Mappe of Commerce (which he had probably read),[2] Petty stipulated that the Office should deal with four separate areas: 'The Historie of Manufactures, Mercature, Stipendiary Offices Publick and Private, and the Historie of Ministrations of all sorts ...' Of these, Petty said that 'the most pleasant and Philosophical, the most honest & innocent, the most advantageous ...' was a History of Trades, or of 'mannuall operations', which should, as he suggested in the Advice, be fully illustrated.

Of the other two essays, the one concerned with Gresham College was almost certainly by Petty, since it is in his handwriting. The other was probably influenced by an earlier draft from his pen. They are closely linked by their common criticism of existing teaching posts and the indolence or ineffectuality of their incumbents. Petty expressed contempt for the lecturing methods at Gresham College, in that many promulgated information which had been published, or would be better suited to a printed, rather than verbal, medium.[3] Even worse, the Professorial Chairs of

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1. Advice, pp.1-2.
2. L.Roberts, The Merchants Mappe of Commerce ... (London, 1638). The Bodleian Library copy, Douce M.737.2, has the initials 'W.P.' in Petty's handwriting, on the inside front cover, and mathematical calculations on the final leaves of the book. See also Lansdowne, Petty Papers, i,189-192, 'In Merchandize', a synopsis of mercantile procedures and skills.
3. However, he did not try to alter Gresham once he became a Professor in 1651: his attention had by then turned to Ireland. For his copy of the College regulations cf. B.H. MSS. 37, Box H, folders 2, i and ii(a).

Divinity, Law and Rhetoric were completely unnecessary, since the universities, church sermons and Inns of Court were more effective and appropriate venues for instruction. In place of the existing system seven lectureships should be created which would deal more with practical, as opposed to theoretical problems, especially those requiring personal demonstration and exposition. To the Chairs of Geometry, Physick, Astronomy and Musick, Petty added three which engrossed 'Magneticall Experiments', practical optics, industrial and experimental chemistry, mechanics, engineering, manufacturing processes 'and all such Trades and practices whereunto are required more Naturall and Mathematicall knowledge then the Common Professors of them are usually instructed in'.

When taken together, Petty's contributions to the debate over the advancement of learning constitute an impressive and stimulating body of material. They were invariably expressed in a taut, effective, and unemotional style, and incorporated detailed and positive proposals. With an admirable, and clear-headed disregard for convention, they called for total reorganisation of England's educational system, and concentrated on utilitarian, mathematical and technological aspects of this programme. In general they probably helped steer Hartlib and Dury towards a more secular[1] and utilitarian approach and, though Petty's social radicalism failed to impress them, Dury's Reformed School[2] and Hartlib's Further Discovery show that these elements left their mark. Finally, the nature of Petty's educational writings during the late Civil War and early Commonwealth periods partly explains his short stay in Oxford. Petty's Baconianism, with its accent on far-reaching social reform, was not acceptable to more conservative, establishment-minded figures like John Wilkins and Seth Ward, as their Vindiciae Academiarum shows:

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1. T.H.Rae, John Dury, op.cit., pp.187-188.
2. Webster, Advancement, pp.151 'Rule 1', 153-155, and 158-159.

> 'Of those very great numbers of youth, which come to our Universities, how few are there whose designe is to be absolute in Naturall Philosophy? Which of the Nobility or Gentry, desire when they send their Sonnes hither, that they should be set to Chymistry, or Agriculture, or Mechanicks? Their removall is from hence ... in two or three years, to the Innes of Court and the desire of their friends is not, that they be engaged in those experimentall things, but that their reason, and fancy, and carriage, be improved ...' 1

After 1660 Petty had little contact with education, except in his support for the schools at Romsey and the training of his own children.[2] As far as method was concerned his short essay entitled 'Exercises of Sense and Reason'[3] evinced a continuing sensitivity to the psychological development of children, and outlined a broader curriculum that included elements of history, law, physical exercise, logic, elementary natural philosophy, technology, medicine and mathematics. In 1681 Robert Wood, after his appointment as Master of Christ's Hospital mathematical School, asked Petty for advice on how to improve the nautical aspects of the curriculum.[4] Petty's letters illustrated his continuing contempt for the unimaginative teaching of grammar schools, reiterated the need for training in mechanics, trades and vernacular languages, and then gave practical instructions about mathematical, navigational, hydrostatic and general naval principles and problems. Once again, as in his earlier essay on Gresham College, the accent was on a well-chosen reading list, coupled with concise instruction sheets and effective tuition by

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1. Published Oxford, 1654, quotation p.50.
2. For this family education cf. Lansdowne, Petty Papers, ii, 4-6. Petty's attitude to his son Charles's education is well expressed in B.H. MSS. Vol.10, 77, letter Charles Petty to Edward Southwell, 5 May, 1687; Brit.Mus.Sloane MSS.2903, ff.42-43, Petty's directions to his sons, Charles and Henry.
3. Lansdowne, Petty Papers, ii, 6-8.
4. For the appropriate letters cf. B.H. MSS. Volume 6, section ii, 81, 84, 85, 94, 36; all letters c.February-March, 1681. See also R.Kirk, Mr. Pepys Upon the State of Christ Hospital (Philadelphia, 1935); A.C. Steward, 'Christ's Hospital and the Royal Society' Notes.Recs.Roy.Soc., 3 (1941), 141-145; Life, Journals and Correspondence of Samuel Pepys, ed., Rev.J.Smith (London, 1841), pp.256-261, 278-279, 286-288, 301-303; The Correspondence of Isaac Newton, ed., H.B.Turnbull (Cambridge, 1967) iv, 112-114.

classroom demonstration. It is interesting to note that Petty's 'Complete Treatise of Navigation', which appeared in Philosophical Transactions after his death,[1] was reprinted in 1779 by Samuel Bentham, as a tabular representation of the navy's official 'System of Instruction'.[2] His division of this complex educational subject was, therefore, judicious, practical and of lasting value.

In the final analysis Petty's changing appreciation of the most effective methods of socio-economic investigation and correction meant that after the 1650s he only discussed educational problems on a few fleeting occasions. His later ideas, while possessing clarity and precision, appeared more as passing comments than as fundamental statements. Consequently, they lacked the profundity of later masterpieces like Locke's work on education, which was itself affected by the Advice. Nonetheless, they were consistent with Petty's earlier dicta, and echoes of these more influential pronouncements can be detected in Sprat's comments on education,[3] and possibly in some aspects of non-conformist academy proposals. Furthermore, Petty's occasional thoughts on the subject demonstrate the homogeneity of his ideas. His criticism of the universities, his belief in the educational role of the Royal Society,[4]

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1. For this cf. Keynes, Bibliography, p.38. For Hooke's parallel ideas on education, geographical discovery and the Royal Society, cf. Royal Society MS. Classified Papers, xxiv, 90, ff.323-324.
2. Sir William Petty's Plan for a System of Instruction Relative to the Business of the Marine Department, in the same words as the original, but with the articles transposed, and marginal titles, supplemental articles, and remarks added (London, June 1779: Chatham Docks).
3. For this unmistakable influence on Locke's Some Thoughts Concerning Education (1693) see The Works of John Locke (London, 1824, 9 vols, 12th Ed.,) viii, 150-202, especially 194-196 on trades. See also Sprat, History, pp.323-331, especially 329; the Quaker tract by J.Bellers, Proposals for Raising a Colledge of Industry of all Useful Trades and Husbandry (London, 1696) embodied many of Petty's ideas and his detailed enumeration of trades, salaries and costs. Cf. ibid, pp.5-9.
4. Cf. Appendix 1, ii, 'To have 20 Schollers to Meet 40 weekes of ye yeare ...' The curriculum for these scholars is given at Lansdowne, Petty Papers, ii, 9-10, 'Methodus ad Magistratum in Artibus (1686)'.

and his continuing advocacy of vocational and technical education also illustrate his life-long disregard for convention and the status-quo. Although it is difficult to gauge the precise effect of Petty's educational writing it is significant that John Aubrey, twenty years after the Advice was published, noted in his important 'Idea of Education' that he must

> 'Peruse S^r W: Pettie's Advice: (in 4 to. 16 --) ... Se[e] those that have Mechanicall Heads (w^ch will quickly be discern'd) Let 'em, on play daies & vacancies practise Drawing, Painting, Turning, Grinding of Glasses for Telescopes, Watchmaking etc ...' 1

(c) Medicine:

It would be unfortunate if Petty's short tract of 1648 was remembered solely for the reasons espoused by Aubrey, or merely as one of many contributions to the puritan programme for educational reform, since the Advice embodied concepts unique in the development of British medicine. Nearly half the pamphlet was concerned with Petty's detailed description of a 'Nosecomium Academicum'.[2] This masterly piece of planning contained a number of startling innovations that were a synthesis of Petty's continental training, his private attitude to prognosis, aetiology and therapy, and his outstanding ability to devise institutional systems which could encourage fertile intellectual developments.

Much of the background to Petty's medical career has already been sketched.[3] The clinical, botanical, chemical, anatomical and philosophical aspects of Leyden's curriculum provided the young Englishman with the

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1. Bodleian Library, MS. Aubrey 10, f.120.
2. Petty, Advice, pp.8-17.
3. For his relations with the medical establishment cf. L.Sharp 'The Royal College of Physicians' op.cit., 120-126, 128. On Paduan medical training, which included similar instructional elements, cf. G.Whitteridge, William Harvey and the Circulation of the Blood (London, 1971), pp.16-36; see also Lansdowne, Petty Papers, ii, 191-2, 'Of Physicians' for Petty's description of the well-balanced practitioner.

most advanced tuition then available in Europe. Subsequent research on optics reinforced his mechanistic attitude to skeletal and anatomic structuralism. His return to England brought experience of clinical practice in various locations and at all social levels. It also provided contact with the schools of Helmontian, Paracelsian and iatrochemical practitioners which proliferated after the destruction of censorship in 1642.[1]

Petty's attitude to medical ideologies was consistent and severe. Thus, in his letter to More of 1649, he forcefully rejected the philosophical apparatus of Galen, Helmont and Paracelsus, and inevitably set himself apart from medical reformers like John Webster who, though influenced by Bacon, were also adherents of natural magic and a complex, iatrochemical world view.[2] To Hartlib, Petty confided that

> 'there cannot bee made at all any satisfactory experiments in medicine much lesse by Glauber. And that the only course in ordinarie is for the present to follow mainly the exampel of Hippocrates by way of industry and observations and by erecting a Nosocomium Academicum ...' 3

Petty, supported by Boyle and Child, also believed that 'Physicians have attained hitherto to better skill to know and discerne diseases than to cure them'.[4] Even then, the medical profession's ability to diagnose the aetiology of most ailments was sadly deficient:

> 'When any disease, paine or other Symptome appeares in the body it is hard to know which of the 6 nonnaturalls was the procatarticke cause thereof, for

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1. For the background to these developments, see L.Sharp, op.cit., 107-109, and articles quoted in ibid, notes 3-5; Partington, History of Chemistry, op.cit., ii, 172-174, 304-312, 380-429. See also Webster, Instauration, pp.246-343; A.G.Debus, The English Paracelsians (London, 1965); ed., A.G.Debus, Medicine in Seventeenth Century England (California, 1974); L.S.King, The Road to Medical Enlightenment 1650-1695 (London, 1970).
2. For Webster's view see his Academiarum examen, pp.72-77, 106-107, in A.G. Debus, Science and Education in the Seventeenth-century: the Webster-Ward debate (London, 1970), and introduction, pp.15-32.
3. Hartlib Papers, MS. Ephemerides, 1648 P-Q1.
4. Ibid, 1650, F-G8.

> wee commonly attribute it to the last takeng hold, swiftest or other disorder the patient committed in any of them ... and then Wee fall a reasoning how the accidents appearing in ye patient may bee produced by Such Causes, whereas sometimes a disease but even now first breakinge forth may bee the fruite of some Morbificall seede long since planted in the body, as for Example the grievous Symptomes following the biting of a Mad dog, pestillentiall aires and contagious touches are not felt till a long time after the infection of the patient, more or lesse according to the disposition of the body to bee wrought upon by the poison and the Nature of the poison itselfe'. 1

Furthermore, diagnostic problems were not only caused by ignorance about basic infectious processes and the logical fallacy of _post hoc, ergo propter hoc_, but also by ignorance about the most obvious bodily functions and micro-structures. Even the body's interaction with 'specific' drugs was uncertain. This explains why Petty chided Boyle in 1653 over his hypochondria and self-medication:

> 'Few terrible diseases have their pathognomonical signs; few know those signs, without repeated experience of them, and that in others rather than themselves. Moreover, the same inward causes produce different outward signs; and _vice versa_, the same outward signs may proceed from different inward causes; and therefore those little rules of prognostication, found in our books, need not always be so religiously believed. Again, a thousand accidents may prevent a growing disease itself, and as many can blow away any suspicious sign thereof; for the vicissitude, where-unto all things are subject, suffers nothing to rest long in the same condition ... [and though] there is a conceit current in the world, that a medicament may be physic and physician both ... for my part, I find the best medicament to be but a tool or instrument ... how few can perform any excellent cures by them ... [and] ... How hard it is to find out the true virtues of medicaments! As I weep to consider, so I dread to use them, without my utmost endeavour first employed to that purpose'. 2

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1. B.H. MSS. Volume 3, item 11 (b), undated, but probably c.1647, since a plan for Petty's _Advice_ is included on the same folio.
2. Boyle, _Works_, (1772 ed.,) vi, 138-139.

In Petty's view there was only one answer to the purely medical aspect of this ignorance, and that was the systematic compilation of accurate case histories by qualified practitioners. To a certain extent aetiological theories would have to wait until the process was well advanced and, even at that stage, compiling the natural history of a simple disease would present enormous taxonomic problems.

To initiate this inductive programme, which Bacon had outlined twenty years before,[1] Petty described an ideal hospital which would provide perfect conditions for academic research and clinical instruction. This constituted the first description in English of a teaching hospital, the institution that eventually helped revolutionise Western medical science and health-care, by the mid-twentieth century. Petty's notes indicate that he took time and trouble over the exact structure of the hospital,[2] and the published description, with its meticulous detail, is proof of his success. Presiding over the institution would be four curators, 'Men of Learning, Honour and Wealth', who were to direct overall policy and maintain moral and financial probity.[3] The medical hierarchy consisted of a senior physician, a vice-physician, and a student; a surgeon, surgeon's mate, and apprentice; an apothecary, apothecary's mate and his apprentice; and a nursing staff composed of regular and occasional attendants. The housekeeping was to be in the hands of a steward.[4]

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1. See Bacon's well-informed analysis of medical science in Works, 484-492 (De Augmentis Scientiarum, Chapter 2). In many areas, except the treatment of scurvy and smallpox, his criticisms would still have been valid in 1820 and 1830.
2. B.H. MSS. Volume 3, item 11 (b). For the background to the development of hospitals, cf. R.Sand, The Advance to Social Medicine, (London, 1952), pp.73-90, 98-100; J.Woodward, To do the Sick no harm ... the British voluntary hospital system to 1875 (London, 1974), pp. 1-16; A.Rosenberg 'The London Dispensary for the Sick-Poor' J.Hist. Med., 14 (1959), 41-56.
3. Petty, Advice, p.10.
4. Ibid, pp.10-11.

All the salaries and personal duties were outlined with precision. The Steward was to be skilled in practical mathematics, especially book-keeping, surveying and architecture. He was also expected to keep a comprehensive account of weather changes, and the concurrent incidence of plant, animal and human disease.[1] Like Sydenham, Locke and Willoughby,[2] Petty believed that such a record would help substantiate or disprove miasmatic theories and the claims of 'Judiciall Astrology'.[3] 'The Physician' said Petty 'must be a Philosopher, skill'd at large in the Phaenomena of Nature'.[4] He was personally responsible for overseeing therapeutic and diagnostic functions in the hospital and, at the end of his tenure, was to compile, from personally verified case histories, a 'Systeme of Physick and the most approved Medicinall Aphorismes'. At all times he should encourage the energetic pursuit of 'Luciferous Experiments' by senior members of the staff, and ensure that procedures and results were recorded accurately. The Vice Physician's main task was to help train the Student, to record the 'History of Patients' and to be present in the wards every day for as long as possible. In all this he was to be helped by the Student, who was also designated to oversee the ministrations of the nurses.[5]

A similar hierarchical structure was applied to the surgeons and apothecaries, whose professional standing received radical upgrading in Petty's scheme. He believed that the medical staff should constitute an interdependent community of brethren,[6] who were seekers after the truth

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1. Ibid, pp.11-12. The salaries were as follows: The Steward, £80; Physician, £120; Vice-Physician, £50; Surgeon and Apothecary, £60 each; Student, £25; Surgeon and Apothecary's Mate, £20 each; Apprentice, £10 each; ordinary Nurse, £4 each; 'Extraordinary' Nurse, 3 shillings p.week.
2. For their later development of this idea see: K.Dewhurst, John Locke, op.cit., pp.18-19, 300-301; idem, Dr. Thomas Sydenham, op.cit., pp.40, 66-67, 86; idem, 'A Review of John Locke's Research in Social and Preventive Medicine'. Bull.Hist.Med., 36 (1952), 317-340, especially 328-330; idem, 'The Genesis of State Medicine in Ireland' Irish J.Med. Sci., 1956 (6th Series), 365-384.
3. Petty, Advice, p.12.
4. Ibid, pp.12-13.
5. Ibid, pp.13-14.
6. Ibid, p.17.

through experiment, observation, and clinical instruction. The hospital would be a dynamic source of progress, accepting and building on clinical natural histories, using chemical, anatomical, surgical, and even astrological procedures and nostrums once successful experience indicated their utility. To back up this team the hospital would possess a full range of facilities including a well-stocked botanical garden, 'Chymicall Laboratory', library, 'Anatomicall Theator', and an 'Apotheca, with all the Instruments and Furniture belonging to each of them'.[1] With the need for practicality uppermost in his mind Petty argued that costing, staff numbers and facilities were all within the parameters of existing institutions. The final, and perhaps most radical, of Petty's suggestions was that the 'Nosecomium' should be allowed to license medical practitioners:

> 'It should be granted by the State, that whosoever hath served his respective time in the Nosocomium, and hath a Certificate thereof from the Society, shall be thereby licensed to practice his profession in any place or Corporation whatsoever, notwithstanding any former Law to the Contrary'. 2

This contempt for the medical establishment's squabbles over status, as exemplified in the pre-war battle for hegemony between the College of Physicians and the Barber-Surgeons, and his total rejection of the Paracelsian and Helmontian Weltanschaung, mark Petty out as a unique and unrepentantly radical thinker. An archetypal Baconian, he believed that only steady compilation of case-histories and comparative data on pathognomic incidence, morbid aetiology, nutrition, specific medicines and anatomical differentiae would provide the certain knowledge which precedes effective medical progress. Although these ideas were later

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1. Ibid, pp.8-9.
2. Ibid, p.11.

developed by Grew[1] and Sydenham,[2] Petty was the first Englishman to give them precise articulation. Nonetheless, he failed to put his theories into practice, because new sensibilities and an increasingly dyspeptic and suspicious view of medicine rapidly directed his attention towards broader problems and fresh solutions.

As a natural corollary of his statistical approach to socio-economic phenomena Petty began to formulate questions which showed a cynical distrust for current medical practice:

> ' Observations upon Physicians
> Vizt:
> (1) Whether [there be] fewer out of the members of the College of Physicians, then out of the like number of any other Society.
> (2) Whether there bee more above 70 yeares old amongst them, then in the like number of any other Society.
> (3) Whether they take as much medicine and remedies as the like number of men in other Societyes.
> (4) Whether of 100 patients to the best physicians aged of any decad, there do not dye as many as out [of] the inhabitants of places where there dwell no physicians.
> (5) Whether of 100 sick of acute diseases who use Physicians, as many dye and [in] misery, as where no art is used, or only chance'. 3

Despite this critical approach, Petty always believed, like many Puritans during the Interregnum, that medicine was 'the most God like of all other facultyes, and is that which our Saviour onely practiced while he was upon

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1. For the similarity of Grew's ideas, a comparison should be made between Brit. Mus. Sloane MSS. 1941. 'Dr. Grew's Papers', ff.59r-61v, giving a list of 110 questions for a history of medical phenomena in Europe, and Lansdowne, Petty Papers, ii, 168-170, 'Concerning the Study of the Art of Medicine'; see also ibid,; 187-189, 'History of Life and Death'.
2. For the seemingly profound effect of Petty on Sydenham (Oxford, 1650-1652) cf. ibid, ii, 168, 'Scheme for a Medical Essay', quoted above, p.102; and Sydenham's views as presented in R.M.Yost, 'Sydenham's Philosophy of Science' Osiris, 9 (1950), 84-105; Dewhurst, Dr. Thomas Sydenham, op.cit, pp.60-67, 101-139; L.S.King, Medical Enlightenment, op.cit., pp.113-133, pointedly disagrees with Yost, but does not deny the importance of empiricism in Sydenham's methodology.
3. Lansdowne, Petty Papers, ii, 169-170.

Earth'.[1] Thus he came to realise that progress in national health-care would come only through the eradication of poverty and malnutrition, the control of infectious disease by isolation, and State organisation of national facilities.

These three goals, while theoretically simple, in practice presented insurmountable problems. The first could only be attained through the creation of new wealth and its equitable distribution, while the other two depended on the social and political attitudes motivating influential figures in government and society, and the ability of the former to impose its will on a disorganised community. Although he realised that this will was singularly lacking in post-Restoration England, and that the medical establishment would bitterly resent his views, Petty continued his advocacy on the grounds of social and medical efficiency. In 1676 he therefore put forward proposals which closely resembled those suggested by Henry Robinson[2] at the height of the reform movement twenty-four years earlier:

> 'Another cause of defect in the art of medicine and consequently of its contempt is that there have not been Hospitalls for the accomodation of sick people, Rich as well as Poor, so instituted and fitted as to encourage all sick persons to resort unto them. Every sort of such hospitalls to differ only in splendor, but not at all in the sufficiency for the means and remedy for the Patients health. For by such means the most able understanding might be encouraged, equally with the best of the professions, to spend and to dedicate themselves wholy to this faculty; and a man shall learn in a well regulated hospitall, where he may within halfe an hower's time observe his choise of 1000 patients, more in one yeare than in ten without it, even by reading the best Books that can be written'. 3

Petty demanded that the State should regulate every aspect of medical

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1. Ibid, 173.
2. See Robinson's succinct demands in Certain Proposalls (1652) op.cit., p.26.
3. Lansdowne, Petty Papers, ii, 175.

practice by providing hospitals, calculating the future national requirement for doctors,[1] constructing adequate training facilities, and paying the salaries of all medical staff.[2] Although anachronistic, it is difficult to avoid the observation that Petty's scheme to some extent foreshadowed the modern National Health Service by two hundred and fifty years.

The other (more traditional) element in Petty's approach was to restrict the spread of contagion by regulating social mobility. Since infectious diseases such as smallpox, influenza and plague were responsible for a high proportion of normal deaths, with spectacular rises in mortality when they became pandemic,[3] and since their aetiology was uncertain, Petty argued that isolation was the only way to reduce the transmission and depradation of these diseases. He outlined particularly detailed plans for London,[4] since urban epidemics were the most devastating,[5] and the capital's population was specially important owing to a concentration of personnel essential to the country's well-being.

Once again Petty's schemes for dealing with a major socio-medical problem, when looked at in their entirety, seem comprehensive and thorough. Firstly, he proposed that

> 'there bee a Councill of Health, viz. for the Plague, acute and epidemicall diseases, aged roundlings, as also for persons and houses of correction, and all sorts of hospitalls and women in child-bed'. 7

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1. Hull, Economic Works, i, 27-28, (Treatise of Taxes).
2. Lansdowne, Petty Papers, ii, 176.
3. See sources summarised in J.D.Chambers, Population, Economy and Society in Pre-Industrial England, (Oxford, 1972), pp.77-106; H.Zinsser, Rats, Lice and History (Bantam, New York, 1960); C.Creighton, A History of Epidemics in Britain (Cambridge, 1894) i + ii.
4. Cf. Lansdowne, Petty Papers, i, 36-37 'Emprovement of London', 37-40 (three essays and notes on the plague).
5. Ibid, i, 274.
6. Ibid, i, 35.
7. See C.F.Mullett, 'Sir William Petty on the Plague' Isis, 28 (1938), 18-25; for quotation cf. Lansdowne, Petty Papers, i, 35.

This council was to be responsible for the creation of 6,000 'Pest Houses', where, isolated from London, everyone suspected of carrying, suffering from, or having had contact with the plague should be kept with proper medical attention and in reasonable comfort. Moreover, if the plague got out of control, a significant part of the working population would be evacuated from the city into the country. Finally, by utilising a crude form of cost-benefit analysis, Petty demonstrated that, should such procedures be implemented, the saving of lives could dramatically outweigh the immediate expenditure:

> 'The value of 140^{m} [e.g. 140,000] people at £90 per head in 12 millions 600 m [600,000] pounds: soe as the Question seems to be what sum of money, and Meanes ought to be prudently ventured for the probable cutting of 3 fifths of this Calamity'. 1

At the very least the government should ascertain whether this type of contingency plan was valuable or not.

Leaving aside the means whereby such statistical information might be gathered and the social laws which might emerge from this data (two central concerns underlying Petty's approach to social problems) a broad, but sufficiently detailed outline of his medical opinions has now emerged. Predictably, he maintained a critical attitude toward all medical philosophies, although like Bacon he had a high regard for Hippocrates.[2] His preference for the systematic collection of nosological histories and associated medical phenomena also linked him closely with the Baconian tradition, and with other doctors such as Grew. Petty also shared some common characteristics with major figures like Sydenham (whose empiricism he may have fostered) and Robert Boyle.[3] However, unlike them,

1. Lansdowne, Petty Papers, i, 274.
2. Ibid, ii, 167.
3. Boyle, however, had far greater belief in the efficacy of medicine, cf. Works (1744 ed.) i, 463-583 (Usefulness of Natural Philosophy, Part ii, Sect 1, 1663 'Usefulness to Physic') and ibid, iv, 325-338 ('Advantages of Simple Medicines', 1685); G.W.Jones, 'Robert Boyle as a Medical Man' Bull.Hist.Med., 38 (1964), 139-152. For Petty's possible contact with Sydenham at Oxford, c.1650-1652, cf. p.106 above.

he began to lose faith in the power of traditional, or even experimental techniques to deal with the root causes of disease, at least in the immediate future, and he therefore took an increasingly cynical view of contemporary medicine per se. Instead he turned to other methods of economic development, preventative control and social analysis, which he believed were capable of producing more rapid and effective improvements in general health care.[1] In this he exhibited remarkable foresight, as recent research into demographic change and the relationship between disease, medical response and variables like class, income, occupation, geographical location, and nutrition are beginning to show. He also described methods that were later developed independently by a small, but significant number of far-sighted authors ranging from the Quaker,[2] John Bellers, to Sir Gilbert Blane, the outstanding nineteenth century physician.

(d) Invention: Double Writing and Naval Research:

The importance of technological innovation to Petty's career has already been illustrated in the Down Survey, while his passion for invention, which emerged after 1646, has also attracted comment. Previous comparisons between these two areas of endeavour have inevitably

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1. Petty's advanced ideas on health care, poverty, and correct methods of research should be compared with nineteenth century developments. Cf. W.M.Frazer, A History of English Public Health, 1834-1939 (London, 1950), pp.1-238.
2. Cf. P.Mathias 'Disease, Medicine and Demography in Britain during the Industrial Revolution' Ann. Cisalpines d'Histoire Sociale, 4 (1973), printed Pavia, 1975) 145-184. The author would like to thank Professor Mathias for an off-print of this valuable survey article; cf. especially pp.168-169. See also J.Bellers, An Essay Towards the Improvement of Physick (London, 1714), echoing Petty's demand for clinical teaching hospitals, a national system of health care, etc; Sir G.Blane, Elements of Medical Logick (2d ed., London, 1821) pp.14 and 137-144, on Baconian methods of medical research, and the intimate relationship between experimental natural philosophy and medicine.

suggested that while he was spectacularly successful with the first, in the second his experience was one of unmitigated disaster. This unfortunate capacity to devise instruments, techniques or projects which were either unwanted or impractical was continued on a larger and more expensive scale after the Restoration, when his fascination for naval affairs encouraged his most grandiose 'folly': twin-hulled ships.[1] Petty's naval research has generally been dismissed as unscientific and humorous. Nonetheless, while his failure is indisputable, it is important to understand the reasons and circumstances which led him to lavish so much energy and expense on such elusive and intractable ends.

As an archetypal inventor Petty belonged to an important seventeenth-century movement. Although at times its developmental pace seemed to slacken,[2] this movement continued to attract many enthusiastic adherents throughout the period. Within its ranks could be numbered diverse figures such as Drebbel, Wheeler, Dymock, Dud Dudley, Plattes, Worsley, Sir Samuel Moreland, Prince Rupert, Yarranton, Christopher Wren, the Marquis of Worcester, Papin, Sir Mathew Hale, Grew, Boyle, Wilkins, Evelyn, and the most brilliant of all, Robert Hooke.[3] At present it is impossible to predicate general reasons which adequately explain this phenomenon, since so many variables regulated the motivation, involvement,

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1. Lansdowne, The Double Bottom or Twin-Hulled Ship of Sir William Petty (Oxford, Roxburgh Club, 1931); Hall, Galileo to Newton, op.cit., pp.339-340; M.H.Nicolson, Pepys' Diary and the New Science, (Virginia, 1965) pp.117-122, 179-189.
2. R.K.Merton, Science, Technology and Society in Seventeenth-Century England (Harper re-print, New York, 1970), p.40, Table 3.
3. For background information cf. Webster, Instauration, pp.324-483; H.M.Rhodes, 'Literary Aspects of Inventors, Projectors and Virtuosi: 1660-1720' (M.A.Thesis, London University, 1959); M.T.Hodgen 'Sir Mathew Hale and the "Method" of Invention', Isis, 34 (1943), 313-318; W.H.Thorpe 'The Marquis of Worcester and Vauxhall' Trans. Newcom. Soc., 12 (1932-3), 75-88; H.Dircks, The Life ... and Scientific Labours of ... The Marquis of Worcester, (London, 1865); H.W.Dickinson, Sir Samuel Morland, Diplomat and Inventor, 1625-1695 (Cambridge, 1970); R.T.Gunther, Early Science in Oxford, op.cit., vols. vi-viii, on Hooke; J.U.Nef, The Rise of the British Coal Industry, (London, 1932), i, 252-257; J.W.Gough, The Rise of the entrepreneur (London, 1969).

proficiency and methodology of individual inventors, Obvious causal factors such as a desire for personal or public profit, deliberate financial chicanery, intellectual curiosity, cogent scientific research or mere good fortune, can be detected in many instances, while the 'literate experience', exemplified in Bacon's works, and energetically supported by many puritans, also had a powerful influence. Beyond this, successful exploitation of a particular invention (however useful) could be encouraged or retarded by many different circumstances, which might encompass inadequate capital support, inherent resistance to innovation, economic expansion or contraction (general and local), the inventor's death or bankruptcy, insufficient demand due to ineffective advertisement, lack of appropriate materials, skilled labour and systems for production, and direct suppression by competing or vested interests.[1] None of these circumstances necessarily operated in every case, and a single one may have been sufficient to decide the result.

A reasonable assessment of seventeenth-century invention and innovation would presently contend that exogenous factors combined with inherent technical deficiencies to restrict the introduction of techniques capable of revolutionising Britain's economy. Instead, slow progress was made through the accretion of small improvements in fields like metallurgy, mining, applied mathematics, industrial chemistry, instrument making, surveying and agriculture. This may have led to a period of 'strategic [economic] advance' between 1660 and 1720, 'when all metals except iron swung onto mineral fuels and such industries as glass and pottery were set within the matrix of a coal-fuel technology'.[2] Nonetheless, the final outcome of current debate over the relationship of 'science' and 'technology', and the diffusion of innovations, cannot be

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1. P.Mathias, 'Skills and Diffusion of Innovations ...' op.cit., especially 93, n.1, 97 n.11-12.
2. Ibid, 107.

decided until a sufficient number of micro-studies have laid a foundation on which axiomatic judgments can be based. It is from this stance that a brief analysis of Petty's general attitude to invention, and his exploits in two specific areas, will be made.

In 1646, when Petty was developing a number of (hopefully) profitable machines, there was a widespread and understandable dichotomy between cynical distrust of projectors, monopolies and patents on the one hand, and support for beneficial inventions on the other. The obvious problem was how to differentiate the second group from the first. Walter Blith, while trying to introduce new agricultural machinery and techniques, also warned his readers against the 'naughty generation of men that have brought an ill report upon Injenuity through their pretences of great abilities in Engineereship ... raising and drawing water ... [and] Chymistry.'[1] Further on in Improver Improv'd he returned to those 'Scandalous' inventors of machinery, highlighting the very problems of scale and stress calculation which Petty tried to answer twenty years later in The Discourse of Duplicate Proportion. These 'Mountebankes' would hold out 'specious pretences of wonders', but their machines for pumping, draining and lifting 'put such an Impossibility unto Tackles, Geares, and Wheeles for holding, that they would all fly in sunder at the very first motion, ... and snap in sunder as fast as mended'.[2] Such suspicions helped cause the penury and early death of inventors like Gabriel Plattes, and distrust for Cressey Dymock, whose evasive pamphlet An Invention of Engines of Motion (1651) was a perfect example of 'projecting' literature.

Recently, Professor Wilson has noted a 'steady change' in the attitude of writers (and entrepreneurs) towards technical innovations, between the publication of The Discovery of a Projector (1641) by Thomas Brugis, and Defoe's Essay on Projects (1697).[3] This may well be true, but Petty was

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1. Blith, Improver Improved, (1652), op.cit., Introduction.
2. Ibid, pp.40-41.
3. C.Wilson, England's Apprenticeship, op.cit., pp.6-7; see also Webster, Instauration, pp.343-355, 'The Burden of Perpetual Patents'.

still convinced in 1662 that the world was generally hostile towards the inventor, and inhospitable to new inventions. When discussing patents in A Treatise of Taxes he justified them on the grounds that, if granted, they gave the inventor a chance to perfect his ideas by obviating plagiarism and unfair competition. The only other justification for a monopoly was 'at the first introducing of a new Manufacture' which required specialised or unfamiliar skills, high capital outlay, and adventurous entrepreneurial judgment. Nonetheless, monopolies granted to encourage inventions, as Petty knew from bitter experience, were usually worthless:

> 'few new Inventions were ever rewarded by a Monopoly [or patent]; for although the Inventor oftentimes drunk with the opinion of his own merit, thinks all the world will invade and incroach upon him, yet I have observed, that the generality of men will scarce be hired to make use of new practices, which themselves have not thoroughly tried, and which length of time hath not vindicated from latent inconveniences; so as when a new Invention is first propounded, in the beginning every man objects, and the poor Inventor runs the Gauntloop of all petulent wits; ... Now not one of an hundred out-lives this torture, and those that do, are at length so changed by the various contrivances of others, that not any one man can pretend to the Invention of the whole, nor well agree about their respective Shares in the parts. And moreover, this commonly is so long a doing, That the poor Inventor is either dead or disabled by the debts contracted to pursue his design; and withall railed upon as a Projector, or worse, by those who joyned their money in partnership with his wit; so as the said Inventor and his pretences are wholly lost and vanisht'. 1

This paragraph realistically describes the common experience of many inventors, which in Petty's case can be illustrated by brief reference to his most significant projects: double-writing and twin-hulled ships.

The circumstances attending Petty's fruitless development of the copying instrument have already been described. The advantages of such a machine in an age when scriveners, amanuensi, and authors could produce

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1. Hull, Economic Works, i, 74-75.

only single copies, should have been manifest. Petty himself maintained that

> 'The use hereof will be very greate to Lawyers & Scriveners for the making of Indentures and all kind of counterparts. To Merchants, Intelligencers, Registers, Secretaries, Clerks or for copying of Letters, Accompts, Invoices, entring of Warrants etc. To Schollers for transcribing of rare Manuscripts, and preserving Originalls from falsification and all injuries of time'. 1

With the increasing complexity of government and commerce, both dependent on documentation, a really functional machine should have guaranteed profitable exploitation. It is therefore important to know why, unlike modern counterparts, Petty's invention was such a failure.

There can be no doubt that the instrument for double, as opposed to multiple, writing was partially effective, since copies of scriptural verse, used as evidence for the petition of Morris and Petty to 'Parliament and [the] Council of State' (August 1649), bear a very close resemblance.[2] Nonetheless, detailed inspection of these two manuscripts (by pressing one on top of the other and utilising a strong light to induce transparency) shows significant divergence in their lettering and spacing. The instrument therefore made two copies simultaneously, but they were not (as claimed)[3] identical. This was probably due to imprecise machining of the brass parallelograms which effected duplication, and more especially of the pivotal joints on which the movement of this simple instrument depended. Also, while its copying speed was probably equal to that of a single pen,[4] the duplicated manuscripts show that the ink supply was

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1. Hartlib Papers, lxxi, 7, f.3, m.s. draft of Petty's broadsheet Double Writing, (dated 6 April, 1648). The pantograph was perfected in 1743 by Langlois. Cf. Encyclopedie ou Dictionnaire Raisonne ... des Arts et des Metiers. (Paris, 1751-1765), Supplementary vol.xi; vol.iii (plates), Plate 3 (pagination irregular); and index 'pantograph'.
2. Pub. Rec. Off. MS. S.P.18, Vol.2, ff.158-159.
3. Hartlib Papers, lxxi, 7, f.2r, 'The nature & uses of ye double writing instrument', note 4.
4. House of Lords, Main Papers, 25 Feb., 1647-8, f.128 r + v, deposition signed by Lodwick, Hartlib, Worsley, Coxe, et al. 'that Wm. Petty produced two copies exactly resembling one another ... being in less time than a professed writer wrote one copy'.

irregular, leading to inexact and, occasionally, indecipherable writing. In legal or business documents these defects, though minor, could prove disastrous if the number '1', for example, appeared to be '7'. The machine was, therefore, only marginally efficient, and in such circumstances imperfection was a serious commercial liability.

In addition to these technical deficiences, others relating to capital support and marketing were also important. Petty spent an inordinate amount of space in A Declaration Concerning the newly invented Art of Double Writing (April 1648)[1] explaining his motive for seeking an official patent, for maintaining silence over the instruments' construction, and in defending its performance. To a large extent these protestations resulted from his inability to finance the cost of commercial development himself.[2] It is quite possible that adequate financial support might have allowed Petty to iron out technical problems of design and manufacture, and to advertise his invention more effectively. Instead, both the patent and his agreement with Henry Morris (September 1648)[3] failed to provide sufficient capital, and he was unable to overcome consumer resistance and instrumental malfunction.

Apart from these impediments, it is possible that Petty's double writing failed because of other external factors. It is significant that the idea of simultaneous copying became commonplace in the early 1650s. Christopher Wren, then a young Oxford prodigy, devised his own version of the instrument independently of Petty, and wrote several letters c.1652-1653 defending his priority of invention.[4] According to Hartlib's Ephemerides the government paid Wren £80 for this machine,[5] and his 'double art of

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1. Cf. Keynes, Bibliography, pp.3-5.
2. These problems are also discussed in Hartlib Papers, lxxi, 7, ff.5 + 6, 'All the wayes of raising profitt from the Invention of double writing being full of unavoidable difficulties ...'
3. B.H. MSS. Volume 8, number 43.
4. Letters in Wren, Works, pp.43-45; Bennett 'A Study of Parentalia', op.cit., 143-145.
5. Hartlib Papers, MS. Ephemerides, 1653. G.G. - G.G.6.

writing [is] practised by some of MR Thurloe's clarks, Greattrick making the instruments for it'.[1] Furthermore, Hartlib's papers contain numerous references to this idea, ranging from Sir Cheney Culpeper's extensive 'discovery' of Petty's technique in a letter of June 1647,[2] to comments in the Ephemerides for January 1651 that 'John Raimond of Sherborne in Dorsetshire' had invented '7-fold writing'.[3] Petty's machine was also known on the continent and Oldenburg reported to Hartlib in July 1658 that he had first heard of the 'Instrumentum Petti' in Frankfort, from 'a Dutchman, yt hath formerly been preacher to hidden Protestants at Collen [Cologne?]'.[4] Eleven years later, Oldenburg acted as intermediary in a three-cornered discussion between Fellows of the Royal Society, notably Wren, Sir William (who was in Ireland), and Christian Huygens.[5] Huygens had invented '[une] Machine pour ecrire sept copies a la fois', describing it in a diagram and commentary, which were subsequentlyly dispatched to the Society.[6] These classic examples of multiple discovery, spread over a period of twenty years, indicate that there was an obvious technical need which cried out for solution. The various inventions, or suggestions, were all closely approximate in design, and the fine tolerances which they required were certainly not beyond the technical abilities of contemporary instrument makers.[7]

Despite such encouraging circumstances it is clear that these writing instruments were not commercially viable. Moreover, as Hartlib reported to Boyle in May 1654, commercial failure was damaging to the inventor's reputation:

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1. Ibid, 1654. *W.W.* - *W.W.7.*
2. Hartlib Papers, viii, 31, ff.1-2, letter dated 25 Jun[e], 1647, discussion accompanied by sketches of the instrument.
3. Hartlib Papers, M.S. Ephemerides, 1651, A.5.
4. Oldenburg Correspondence, i, 170-171, letter dated 18 July, 1658.
5. Ibid, v, 557-8, 582-3, c.May 1669; vi, 45-46, 93, 163, c.June-July, 1669.
6. Royal Society MSS, Classified Papers, xvii, 16.
7. For such accurate work cf. Dickinson, Sir Samuel Moreland, op.cit. pp. 28-33, on the calculating machine by Sutton and Knib, 1666.

> 'I wish that Dr Petty would shew himself to the world by some rare piece or other. For since the non-performance or non-divulging of the invention of his double writing, his credit is mightily impaired in England, and other nations which have heard of it. Those that know the way, which MR Wren doth use, say his [i.e. Wren's] art of double writing is not worth a rush; for it can never be readily practised'. 1

To the limiting factors of technical deficiency, inadequate capital, and inefficient public relations, should surely be added the important problem of competing interests. The scrivener's profession was, after all, thriving, and many skilled men would have been thrown out of work by the introduction of an efficient machine. Since its simplicity of design and construction meant that the controlling disincentive was not necessarily due to technical problems, it is possible that this additional factor helped constrain, or even suppress, its exploitation.

In the final analysis, the double-writing instrument is important not only because of its commercial failure and technical imperfection, but also because three leading figures, while disparaging its simplicity,[2] took an active interest in the machine's development. From this it would appear that experimental natural philosophers regarded 'applied science' or 'technology' (however simple), as socially and intellectually valuable. It also suggests that the attempt by historians to discriminate between 'pure' and 'applied' science is inappropriate within some seventeenth-century contexts,[3] and that their division of the broad spectrum of interests which absorbed contemporary natural philosophers is both arbitrary and misplaced. Additional evidence to support these contentions is readily supplied by brief analysis of Petty's naval experiments.

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1. Boyle, Works (1772 ed) vi, 88.
2. For this cf. Wren, Works, p.44; Petty, A Declaration [about] Double Writing, op.cit., p.2.
3. Cf. A.R.Hall, 'Merton Revisited, or, Science and Society in the Seventeenth Century', Hist. Sci., 2 (1963), 1-16, especially 6-10; criticised in A.E. Musson, E.Robinson, Science and Technology in the Industrial Revolution (Manchester, 1969), especially pp.4-7, and 10-30; P.Mathias 'Who Unbound Prometheus? Science and Technical Change, 1600-1800' in ed., A.E.Musson Science, Technology and Economic Growth in the Eighteenth Century, (London, 1972), pp.69-96; Hall, Ballistics, op.cit., pp.158-165. This assessment is reinforced by the continuing interest of many Fellows in the history of trades and associated technology. See chapter 1, section 'f' above.

Hydrodynamics and naval design present some of the most difficult problems that human ingenuity has needed to solve.[1] The mathematics of irregular cylinders and curved bodies is, in itself, extremely complicated. When these three-dimensional problems are added to that of displacement caused by the motion of such forms through fluids, especially where this is combined with the effects of shape, friction and surface area (i.e. resistance), it is obvious that a high order of analytical complexity has been reached. If, in addition to such considerations, those of ballast, rigging, wind direction and velocity (at different heights), aerodynamic resistance, pitch, yaw and hull stress are included within the analysis, the variables become so complex that, even now, they defy precise definition en masse. Predictively, and analytically, the only solution is for the problem to be broken down into its constituent parts, for these to be solved individually, and for designs based on the resulting approximations to be tested in miniature. Only then can a full-scale hull be built with any reasonable expectation of success.

Given this order of complexity, it is not surprising that ship design long remained a craft based on intuition and traditional practice, rather than an 'exact' science. The very concept of isolating constituent factors was a notable step forward, but it took nearly two hundred years before adequate development led to the research and solution by Froude (between 1872 and 1879).[2] As usual, progress was encouraged by the requirements of warfare

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1. For background material cf. R.G.Albion, Forests and Sea Power: The Timber Problem of the Royal Navy 1652-1862 (Connecticut, reissued 1965); idem, Naval and Maritime History, An annotated Bibliography (4th Ed., Newton Abbot, 1973); G.S.Baker, 'Development of Hull Forms of Merchant Vessels' Trans. N.E.Coast Inst. Engineers. Shipbuilders, 54 (1938) 33-66; R.Davis, The Rise of the English Shipping Industry, (Newton Abbot, 1972); J.Fincham, A History of Naval Architecture (London, 1851), especially pp. ix-xvii; H.I.Chapelle, The Search for Speed under Sail, 1700-1855 (London, 1967), pp.xv-25; F.L.Robertson, The Evolution of Naval Armament (London, 1921) pp.10-37; R. & R.C. Anderson, The Sailing Ship, Six Thousand Years of History (London, 1926); Merton, op.cit., pp.179-183, 239-245; G.B.Naish 'Ships and Shipbuilding' in Singer, Technology, op.cit., iii, 471-500.
2. Cf. W.F.Stoot, 'The Researches of William Froud ... On the Resistance of Ships: The History of the Formulation of empirical laws concerning the resistance encountered by bodies moving through the water and the first successful application of such laws to ship like forms by Froude (1810-1879)' (M.Sc. Thesis, University of London, 1956).

and commerce, which reinforced more abstract intellectual concern. Initiating this long parturition, early attempts at analysis can be detected in England from the first decades of the seventeenth century. Thus, interest in nautical technology was expressed by several of Hartlib's protegees.[1] The next 'generation' of natural philosophers included Wren, Wallis, Boyle, Hooke, Halley and Newton,[2] who were all involved with particular aspects of naval design. This period also witnessed more traditional refinement of practical shipbuilding, exemplified in the work of the Pett family and Sir Anthony Deane.[3] In fact, many individuals investigated a wide variety of nautical problems, often with a conspicuous, but understandable lack of success.

There are several valuable sources for seventeenth century English naval developments which contain accounts of numerous experimental projects by obscure figures. The papers of Samuel Pepys[4] embody a wealth of such activity, as do those at the Royal Society which relate to maritime questions.[5] These sources largely remain unstudied, at least with regard to contemporary pressure for technical innovation and diffusion of naval technology.

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1. Cf. Sheffield University, Hartlib Papers viii, 53, ff.1-6 'Inventions for Shipping;' MS Ephemerides, 1648, O-P.3, O-P.6; 1650, E-F.5; 1653, F.F.-F 1, F.F.-F.F.6/7.
2. On Wallis and Wren cf. Bennett 'Wren' op.cit., pp.231-241. On Newton cf. I.B.Cohen 'Isaac Newton, the Calculus of Variations, and the Design of Ships' in ed., R.S.Cohen, For Dirk Struik: Boston Studies in the Philosophy of Science, vol.xv, pp.169-187. On Boyle see Pett's letter to Pepys, 3 May, 1696 in ed., J.R.Tanner, Private Correspondence ... of Pepys 1679-1703 (London, 1926) i, 112-116; R.E.W.Maddison 'Studies in the Life of Robert Boyle, F.R.S. Part II: Salt Water Freshened' Notes. Recs. Roy.Soc., 9 (1951-52), 196-213. On Halley cf. MacPike, Halley Papers, op.cit., pp.144-165, 225-226. See also K.T.Hopper Common Scientist, op.cit., pp.142-147.
3. G.A.Callender, Peter Pett and the Golden Sovereign (London, 1930); Magdalen College, Cambridge, Pepys MSS. 2910; 2873 pp.259-260; 2501 are all examples of Deane's often brilliant technical work.
4. Cf. ed., J.R.Tanner, Bibliotheca Pepysiana: A Descriptive Catalogue of the Library of Samuel Pepys (London, 1914) i, 'Sea Manuscripts'. For examples see, Pepys. MSS. 1074 'Mr. Dumer to Mr. Pepys about Improveing ye Art of Building Shipps'; Pepys MSS. 2643; Pepys MSS. 1731 'Of Navarchi ... [by Samuel] Fortree'.
5. Royal Society MS. Classified Papers vii (1) 'Architecture, Shipbuilding ... [etc.]; ibid, xxv, 'Political, Trade ...', items 114-116. For information on the Society and naval affairs see 'William, Viscount Brouncker, P.R.S.' in Hartley, Royal Society, op.cit., pp.147-157.

Unfortunately, given the present confines of space, it is impossible to attempt even a general analysis of such materials here. Instead, a brief account of the more obvious aspects of technical innovation will be followed by an outline description of Petty's own unfortunate experiences, concluding with a more detailed investigation of his methods of research.

The specific features of any sailing ship depend on a complicated blend of functional requirements. Thus, a vessel engaged in the carriage of bulky objects demands high volume, low manning levels, uncluttered cubic capacity, maximum stability and easily managed rigging.[1] Rapid transit may not be essential. On the other hand, a ship carrying valuable articles such as spice or bullion probably requires speed, defensibility and a rugged construction, rather than sheer volume or low manning ratios.[2] In some circumstances, a compromise between the two types is demanded by adverse conditions such as piracy, and the double requirements of martial and peaceful use. Strategic and commercial pressures, in addition to intrinsic problems of design and construction, therefore play a major part in the formulation of every vessel.[3] Such factors also multiply those variables which control the rate of innovation and diffusion of improvements, particularly when political or military circumstances are unpredictable or generally hostile. Naturally, if a single configuration caters for all the critical factors its adoption may be general and rapid.

In the seventeenth century, the ideal vessel was one that had a shallow draught, large, uncluttered capacity, strength, stability, space for heavy armament, speed, good sailing qualities, low manning ratios and constructional simplicity. Any ship that possessed this extraordinary

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1. A classic example of such development is the spread of the Dutch 'fly-boat' during the seventeenth century. Cf. V.Barbour 'Dutch and English Merchant Shipping in the Seventeenth Century 'Econ. Hist. Rev., 2 (1930), 261-290.
2. Chapelle, Search for Speed, op.cit., pp.3-5, 10-11.
3. Cf. D.C.North 'Sources of Productivity Change in Ocean Shipping, 1600-1850' J.Polit.Econ., 76 (1968), 953-967; G.M.Walton 'Obstacles to Technical Diffusion in Ocean Shipping, 1675-1775' Exploration in Econ. Hist., 8 (1970-71), 123-140.

blend of characteristics would, one might think, have been guaranteed success. In theory, at least, it should have been possible to devise a hull form which produced the maximal compromise between these sometimes conflicting requirements. In Petty's view there was certainly no prima facie reason why such a design exercise should not be attempted, even if it meant consideration of some extremely unusual configurations.

Between 1660 and 1687 Petty was therefore involved in the development of twin-hulled ships of varying sizes, shapes and structures.[1] Five 'working' vessels were produced, at great personal expense, and with different levels of success. The final version, which has not hitherto attracted attention, successfully sailed after Petty's death:

> '... I believe it will be acceptable to yu to have ye acct I lately receiv'd from my Uncle James of ye double-bottom Boat, wch he tryed according to directions he had from my dear Father ... as follows viz't that ye double Bottom Boat wch I built by yor Fathers directions does Everything yt he expected from her and to yt degree yt for ys very Invention (to say nothing of his other Perfections) he deserves to have his statue erected. I was [in] her at sea for about 12 dayes together in [which] times wee met with variety of weather, and in ye Company of 7 ships for some time, but did wrong them all upon a Wind ..." 2

Of the four previous vessels, one dating from 1684 was a 'sluice-boat' with a twin-keeled, as opposed to a twin-hulled, configuration. This was monumentally unsuccessful. The previous three, each one larger than the

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1. Note Petty's comments (c.1648/9) over the reform of Gresham College and the need for instruction in, and development of, 'Ships for burthen and swift sayling', Webster Instauration, p.551. For information on these vessels see Lansdowne, The Double Bottom, op.cit., passim. Useful summaries of Petty's trials are in Strauss, Sir William Petty, pp.115-119; Keynes, Bibliography, pp.43-45. Additional information is in Sprat History, pp.240-241; Birch, History, especially i, 183-193; ii, 40, 42; iv, 286-287, 346-352. Evelyn, Diary, iii, 304, 369; Pepys, Diary, iv, 256-7, 262-3, 437; v, 24-25, 28-30, 47, 353; vi, 38, 63. A diagram of on version of the boat is at Birch, History, i, end (plate 2); Lansdowne, Double Bottom, Plate 1, gives three pictures of a model of the boat currently at the Society, and plates 2-4, are further illustrations of different boats.
2. B.H. MSS. volume 10, letter 114, Charles Petty to Edward Southwell, 14 September, 1688.

other, were developed by Petty between 1662 and 1665. They were true catamaran-type vessels, with two parallel and separate hulls. The last of these, the Experiment, was definitely seaworthy and reached Portugal in 1665. Sadly, it foundered in a massive storm on its way back to England (along with 70 more traditional sailing ships) primarily because most of its crew had been press-ganged.[1] The preceding vessel, Invention II, actually won a race between Dublin and Holyhead in bad weather conditions. The basic sea-worthiness and moderate design success of four out of five of these ships is therefore historical fact. Any view which does not recognise this merely echoes the abusive,[2] ill-informed, and even jealous opinions of certain contemporaries. Moreover, these superficial accounts fail to raise important questions. For example, were Petty's methods of research into hull design conducted in a scientific fashion? Given its modest success, what were the disincentives restricting the vessel's development and diffusion? At worst, what were the factors which produced fundamental design-failure?

There can be no doubt that Petty's attempts to isolate some of the important variables affecting hull resistance and displacement, by empirical and mathematical means, were both rigorous and outstandingly creative. His basic method was the utilisation of simplified shapes which were pulled over tanks of water, using carefully measured impellant forces.[3] This later became a fashionable exercise,[4] but the evidence contained within Lansdowne's

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1. Anthony Wood's account, quoted in Keynes, Bibliography, pp.44-45, is supported by Petty's own description given in B.H. MSS.36, Box G, 21, i, 'A dialogue concerning Shipping,' pp.3-4.
2. See the scathing satire in Brit. Mus. MSS. Sloane 360 'Itur Hibernicum or, the Ramble Being the Voyage and Adventures of Three Knights Errant Also A Poem on the Double-bottom'd Ship built at Dublin ... 1675', especially ff.73-80.
3. Lansdowne, Double Bottom, pp.6-24, two essayistic fragments on hydrostatics, naval experiments etc., undated but probably c.1662-4. First printed 1931.
4. Cf. Brit. Mus. Sloane MS. 2754, giving details of similar experiments c.1670. Dr. Latham, Pepys Librarian at Magdalen College, Cambridge, suggests that this short anonymous essay was by Henry Schere, a colleague of Pepys. See also Pepys MS. 1731, 'Of Navarchi' by Fortee, which also contains an account of such experiments, and Baker 'Development of Hull Form', op.cit., 39, 66 for analysis of these trials.

study shows that Petty's experiments were the earliest, most scientific and most numerous. Furthermore, his attempts to break down the immensely complex factors surrounding this subject, and his general methodology (in which as many aspects as possible were measured and quantified), foreshadowed the work of Froude two centuries later. Thus, Petty's statement that:

> 'If you would accelerate the progression of the said body to a double swiftness then you must quadruple the potentia. If you would have the swiftness trebled, add 9 times the first potentia; and forward according to square Numbers until the Motion of the body through the water be near as swift as that of the leaden weight is through the Air; for quite as swift it never can be, no more than a ship can sail quite as swift as the wind bloweth ...' 1

bears a close resemblance to Froude's demonstration that:

> 'As dependent on differences of speed it appears that, up to about 8 knots, the resistance is almost exactly proportioned to the square of the speed; with normal displacement and trim it is thus exactly expressed in pounds by the term $88v^2$, being about 5,600 pounds at 8 knots. Above 8 knots it increases more rapidly so that at 12.3 knots, the highest speed attained, instead of being only 14,400 pounds, as it would have been if the law had been unchanged, it had gradually risen to 24,000 pounds'. 2

By using models, framing mathematical laws based on empirical data, isolating basic factors surrounding hydrodynamics and hull design, and applying lessons learned inside the laboratory in full-scale trials, Petty unarguably proceeded along scientific lines.

Like his earlier copying inventions, the twin-hulled ship primarily failed because its technology had not been perfected.[3] In fact its hull configuration had to wait for modern methods of mechanised propulsion

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1. Lansdowne, Double Bottom, p.16.
2. Stoot 'Researches of Froude' op.cit., p.98; see also pp.99-100, 120-122 for further comparative material.
3. A technical account of these vessels' characteristics is given in E.C.B. Corlett 'Twin Hull Ships' paper presented to Roy.Inst.Naval Architects 26 March, 1969, pp. 1-5. Further material in National Maritime Museum MS. SPB/16.

before becoming viable.[1] Nonetheless, there were other factors which provided strong disincentives for its adoption and development. Although in principle it seemed to meet most of the criteria predicated for the ideal seventeenth century vessel[2] and should therefore have been acceptable, the reality was entirely different. Thus the government, and notably the monarch himself, was deeply concerned lest the diffusion of this design eradicated England's acknowledged superiority, which depended on the deep-hulled construction of her fighting ships. Charles himself noted that he

> 'should be sorry it succeeded in Great, for then the Hollanders would have as much advantage of us as we have now of them. Because as ships are now built, they can have none so good as ours, but must draw more water than their Harbours allow' 3

Whatever Petty said about the virtues and invincibility of a combined fleet of both types, he could not avoid this suspicion.[4] Secondly, there was much professional jealousy towards Petty's design on the part of more traditional builders. Pepys caught the tone of this often hypocritical concern:

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1. Details of the 'Barge aboard Catamaran' or BACAT, have been obtained from her owners. Their specification stressed that this twin-hulled ship breaks new ground: 'With a Ship of such a special kind there was no experience from previous new buildings, so very substantial research has been carried out [in a Copenhagen laboratory] e.g. resistance tests (model tests - self propelling), seakeeping tests; test-propelling in waves - wind resistance'. Petty's development techniques, though crude, were essentially the same as these modern ones. He was also sensitive to the value of mechanical propulsion. Cf. Fitzmaurice, Life, p.122, which is a transcript of B.H. MSS. 37, Box H, 1, 'An Attempt to demonstrate that an Engine may be fixed in a good Ship of 5 or 600 Tonn ...' (c.May, 1673).
2. Thus, see Lansdowne, Double Bottom, text of plate 3, following p.86, giving the twelve advantages of the boat. These were also relayed in a report in Journal des Scavans, c. December, 1664, reprinted in the edition of the Journal (for the years 1664-65, published Amsterdam, 1679) pp.43-46.
3. Lansdowne, Double Bottom, p.65. The Dutch were indeed very interested cf. ibid, p.31.
4. Ibid, pp.67 and 69.

> 'Comissioner Pett thence with me, and all alone dined together ... He was mighty serious with me in discourse about the consequences of Sir W.Petty's boat, as the most dangerous thing in the world if it should be practised in the world, by endangering our loss of command of the seas and our trade while the Turkes and others shall get the use of them, which, without doubt, by bearing more sail will go faster than any other ships; and not being of burden, our Merchants cannot have the use of them, and so will be at the mercy of their enemies - so I perceive he is afeared that the Honour of his trade will down, though (which is a truth) he pretends this consideration to hinder the growth of this invention' 1

Pepys also noted that Petty was 'abused the other day, as he now is, by tongues that I am sure speak before they know anything good or bad of [the boat]'.[2] Even if the ship had been more successful, it might have been dangerous for its designer owing to the fears of government and the envy of contemporaries. As it was, the sinking of the Experiment, and the disastrous performance of St. Michael the Archangel in 1684, guaranteed the project's ultimate failure. It also greatly damaged Petty's reputation. The civil-servant-cum-technologist with his solid, indeed brilliant achievement in Cromwellian Ireland, now appeared as a knight-errant involved in the most improbable venture:

> 'You will say the Double bottome hath poysoned all my proposalls; to which I say that the Closett I showed you, containes the solution of all Questions in Shipping and Sayling. A vehement Combination against me made the fourth attempt worse than the first. I courted the King's Mysteryes, and like Actaeon would have seen Diana nacked, and was therefore sett upon by many Cruell dogs'. 3

Southwell supported this judgment with poignant realism: 'You doubtlesse touch a very sore place when you suspect the surviving malice of the Double ship ... And doubtlesse the other great things you mention may

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1. Pepys, Diary, v, 28, entry for 27 January, 1664.
2. Ibid, 25, 22 January, 1664.
3. Lansdowne, P.S.C., p.283, Petty to Southwell, 16 August, 1687.

be as Rationally founded, though unequally comprehended.'[1] When even the Royal Society refused to back Sir William, through fear of government hostility, what chance did his method of investigation have of receiving adequate support?[2] In France, the attitude was different. As the Journal des Scavans noted:

> 'And certainly, should there be no unknown cause to impede its course or to render navigation more dangerous, then there is no apparent reason why this project should not succeed. In that case, many things which have been observed up till now in naval architecture will need to be changed: and learned men will have something on which to exercise their minds in researching into the causes underlying this new type of dynamics to be observed in the motion of this ship'. 3

It was a long time before Petty's fertile methods of nautical research spontaneously reappeared in England, thereby ushering in a revolution in maritime technology. Meanwhile for the next 150 years French naval design and theory, backed by the government, led the rest of Europe.[4]

The last significant element in Petty's attitude towards invention and technology was its link with theoretical aspects of his economic views. One of his most famous pronouncements was 'That labour is the Father and active principle of Wealth, as Lands are the Mother'.[5] In other words, his equation describing the creation of wealth stressed the importance of the active human input. Petty objectively established this crucial

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1. Ibid, pp.286-7, 28 September 1687.
2. Lansdowne, Double Bottom, p.72, quoting a Society Council Minute, 27 May 1663 '... the committee should be put in minde by the Secretary that the Matter of Navigation being a State Concerne was not proper to be managed by the Society'. This rejection caused Petty to make a bitter retort. Cf. B.M. MSS. 36, Box G, 21, ii, giving twelve reasons why it should be concerned, ending with: 'If ye Society shall deferre to owne and countenance such designes till many ages and countryes have allowed them, how doth their usefullnes appeare to ye world?'
3. Op.cit., p.46; translation kindly supplied by R.A.G.Pearson, lecturer in French, the Queen's College, Oxford.
4. Robertson, Evolution of Naval Armament, op.cit., p.36 et seq.
5. Hull, Economic Works, i, 68, checked against the 1679 edition of Treatise of Taxes, p.47.

concept in his Verbum Sapienti,[1] by employing hypothetical quantification in a simplified form. What is important here, is that this stress on the value of labour not only encouraged him to suggest educational and socio-medical reforms (as we have already seen) but also led him to a profound understanding of economic growth. He realised that England needed an agricultural revolution which would release extra 'hands' from tending the 'Lands' of the country:

> 'By the same way we must make a Par and Equation between Art and Simple Labour; for if by such a Simple Labour I could dig and prepare for seed a hundred Acres in a thousand days; suppose then, I spend a hundred days in studying a more compendious way, and in contriving Tools for the Same purpose; but in all that hundred days dig nothing, but in the remaining nine hundred days I dig two hundred Acres of Ground; then I say, that the said Art which cost but one hundred days Invention is worth one Mans labour for ever; because the new Art, and one Man, perform'd as much as two Men could have done without it'. 2

The new pool of labour could then be redeployed in manufacturing activity, allied services and transportation.[3] This would obviously require government control to avoid social dislocation and speed the development of new industries. In essence, therefore, Petty predicted the remarkable transition which later changed England's agricultural and rural economy, into an industrialised and urbanised one. Although he underestimated the horrendous social effects of such redeployment, which were cruelly evident

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1. Hull, Economic Works, i, 103-110; cf. Keynes, Bibliography, pp.34-5; Letwin, The Origins of Scientific Economics (London, 1963) pp.136-7.
2. Hull, Economic Works, i, 182 (Political Anatomy).
3. Cf. Hull, Economic Works, i, 307 (Political Arithmetick) 'Chap.VIII. That there are spare Hands enough ... to earn two Millions per annum more than thay now do; and that there are also Employments, ready, proper, and sufficient, for that purpose.' Petty described this process as 'Superlucration'. Cf. also ibid, i, 118-120 (Treatise of Taxes) 'Chap.X : How to employ the People, and the End thereof'; ibid, i, 213-223 'A Report from the Council of Trade in Ireland ... 1676'.

in the nineteenth century, he also gave a theoretically consistent account of the economic potential of this change, and laid great stress on a social justice which adequately rewarded those working in the nation's new industrial machine.

Ultimately, this vision depended on his belief in the power of invention and the diffusion of new technology. Whether in optics, engineering, agriculture, naval-design or a secretariat the key point was that efficiency should be raised and labour redeployed into more profitable activity. However, Petty did not simply advance this developmental theory on the basis of intuitive belief. On the contrary, he tried to quantify the benefits and, in so doing, utilised and advanced other skills fostered by his early experience. It is these techniques that now require detailed analysis, and perhaps the best locus for such investigation is provided by <u>The Discourse ... of Duplicate Proportion</u>.

Chapter 3

The Discourse Concerning the Use of Duplicate Proportion: 1674

'Pondere, Mensura, et Numero Deus omnia fecit:
Mensuram et Pondus Numeres, Numero omnia fecit.' -

Title page, The Discourse ... of Duplicate Proportion

'The words considerably bigger having been used in some things, that were read, Sir William Petty cautioned, that no word might be used but what marks either number, weight, or measure.' -
Thomas Birch, The History of the Royal Society, iv, 193

'4°. I take notice of what yo^{w} say of ye stock of Mine, Coales, Cordwood, Killowen House ... [but] ... Remember: 1: [to keep a] Journall. 2. To see wth yo^{r} owne Eyes. 3: To Express all in Number, Weight & Measure' ... Petty to Cornet Bunworth, a rent collector in Kerry, letter dated London, 3 November, 1674. B.H. MSS 19, pp.308-309.

Thursday Decem. 10. 1674.

At a Meeting of the Council of the Royal Society.

WHereas it was desired by the Royal Society, *that a Discourse made before them by Sir* William Petty *Knight, at their Meeting the* 26. *of* November *last, might be Printed: It is this day Ordered by the Council of the said Society, That the said Discourse be Printed by the Printer of the Royal Society.*

BROUNCKER, P. R. S.

THE DISCOURSE Made before the Royal Society The 26. of *November* 1674. Concerning the Use of Duplicate Proportion In sundry Important Particulars: Together with a *New Hypothesis* of *Springing* or *Elastique* Motions.

BY Sir *WILLIAM PETTY*, Kt. Fellow of the said Society.

Pondere, Mensurâ, & Numero Deus *omnia fecit: Mensuram & Pondus Numeret, Numero omnia fecit.*

LONDON: Printed for *John Martyn*, Printer to the Royal Society, at the Bell in St. *Paul's* Church-yard, 1674.

This small tract, published at the request of the Royal Society, is the least well-known of Sir William's later works. Unlike his Treatise of Taxes[1] or Political Arithmetick, the Discourse has never been reprinted and has never attracted the same level of interest as his more extensive publications. Even on a superficial level the reasons for this lack of attention are not hard to trace. For example, the Discourse was never designed as a major contribution to contemporary natural philosophy and was therefore not in wide circulation. Its diminutive size and consciously essayistic form were also factors tending to obviate any permanent scientific role, while the repressed but evident tone of polemical immediacy also contributed to its transitory effect. In more recent years historians of science have been dismissive, finding the work confused or insignificant in its apparent failure to enunciate novel theories or describe experiments of major scientific importance.[2]

This neglect and low estimation on the part of some contemporary readers and later commentators has been based more on a failure to appreciate the intended function of the treatise, and its immediate historical context, than on the intrinsic merit of the work. Furthermore, when these factors are fully understood, they illuminate Petty's involvement with natural philosophy in 1674 and the climate of opinion both within the Royal Society and the more hostile environment of the outside world.

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1. Petty's Treatise of Taxes was reprinted five times between 1667 and 1689, and his Political Arithmetick appeared four times between 1683 and 1751. Cf. Keynes, Bibliography, pp.8-10, 21-22, and 31-33. See also: ibid, Number 16, pp.12-15 for The Discourse of Duplicate Proportion (henceforward referred to as Petty : Discourse.) see also Wing, Short Title Catalogue, (1641-1700), (New York, 1951), no.1919.
2. For example see, I.Todhunter: A History of the Theory of Elasticity and of the Strength of Materials, (Cambridge, 1886) i, (1639-1850), 4: "Although absolutely without scientific value, this little work throws a flood of light on the state of scientific investigation at the time ..." Todhunter continues in ironical vein finding Petty's vitalistic atomism a subject of amusement.

A crucial element of understanding has been provided by the discovery(at Bowood House) of the work in its original manuscript form with Petty's own corrections, along with a large amount of epistolary evidence which directly outlines the response of contemporaries to ideas contained in the treatise. There are also Petty's comments and rejoinders to these critical opinions and two valuable lists of people who received copies from the author when the book first appeared. Further evidence on the impact of the Discourse is available from other unutilised sources, both published and manuscript. It is hoped that the combination of all this material will provide an unusually complete historical analysis of the evolution, scope and effect of a single seventeenth-century work. At the same time such an analysis, due to the tract's role as a microcosmic statement of the author's principles, will illuminate the fundamental unity of thought which underlay Petty's work in technology, economics and mathematics.

(a) The Royal Society : declining fortunes 1666-1672

In July 1673, Sir William returned to London after six long and troubled years in Ireland. During this period his main concern had been to protect his legal claim to extensive landed possessions around Dublin and in the County of Kerry. He had also devoted a disproportionate amount of his abundant energy fighting the Irish tax farmers. As a result of these legal and financial entanglements Petty failed to maintain regular contact with the Society, and when he came back to London that summer he quickly reported to Wood that the institution appeared to be in dire straits:

> 'Good Friend I have been neare this place about 12 dayes ... [and find that] ... The Death of the Bishop of Chester and Sir Robert Moray is like to prove fatall to ye Royall Society'. 1

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1. B.H. MSS. 19, pp.172-173. John Wilkins, Bishop of Chester, died in 1672 and Sir Robert Moray in 1673.

Then, in a direct comparison with the Society's lack of state financial support he added:

> 'The King of France is straingely Munificent
> to such a Society of his, late Institucioned,
> payes ym well and requires much from them.' [1]

By 1673, the Society was undoubtedly in a much worse condition than most of its contemporary advocates or some subsequent historians have openly been prepared to accept.[2] Petty's comments highlight how serious the loss of two of the leading members was to this infant institution which possessed such little organisational resilience. In fact,at this point in its history it was beset on all sides by opposition, apathy, disinterest and faction.

After the initial burst of enthusiasm which led, for example, to vigorous signs of support for corporate activity through the foundation of committees like that for the History of Trades, the Society's work and fortunes were disrupted by the onslaught of the plague and the disastrous Fire of London.[3] John Evelyn's optimistic statement in 1666[4]

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1. Ibid., p.173. Letter dated 2 August, 1673. For French government support of the Academie cf. Hall, Galileo to Newton, op.cit., pp.147-155; J.E.King Science and Rationalism in the Government of Louis XIV, 1661-1683 (Baltimore, 1949); E.G.R.Taylor, The Haven Finding Art, (London, 1953) pp.236-244.
2. Comprehensive amplification of material in sections (a) and (b) of this chapter is in M.C.W. Hunter 'The Social Basis and Changing Fortunes of an Early Scientific Institution: an Analysis of the Membership of the Royal Society, 1660-1685' forthcoming article, Notes, Recs. Roy. Soc. which was kindly shown to the present author in draft form.
3. The Society met at Arundel House between 1666 and 1673, during the occupation of Gresham College by the Royal Exchange. The facilities and location of Norfolk's residence proved unsatisfactory. For the Society's return to Gresham cf. Birch, History, iii, 100-101; for the financial effects of the Fire cf. Oldenburg, Correspondence,iii, 226-227.
4. Letter Evelyn to Mrs. George Evelyn at Wootton, Surrey, 29 January, 1666: "We are meeting afresh at Gresham Coll: and have purchased for us, since these days of separation, the fullest, and certainly noblest collection of natural raritys of all kinds that is this day in Europe to be seen: Tell Mr Bohun, The Royall Society is not at an end, florit floreat...", S.J.Davey: Catalogue of Historical Documents and Autograph Letters, xxxi, (1889) p.8.

that, 'The Royal Society is not at an end, florit floreat' failed to acknowledge the inherent problems facing the institution, which became increasingly obvious as the decade progressed. An indication of this deteriorating situation is the decline in recruitment, which dropped from twenty-seven in 1667, to five in 1671 and seven in 1672.[1] If the flow of new members declined then so did the support shown to the Society by a number of prominent Fellows. For example, Evelyn's energies were absorbed for several years as a Commissioner for the Sick and Wounded during and after the Anglo-Dutch war; Hooke was increasingly committed as one of the surveyors responsible for the reconstruction of the capital, and Petty's extended visit to Ireland precluded any direct work on behalf of the Society. Such absences, or the additional burden on the energies of many leading Fellows, meant that they were less able to provide written material or actively participate in the Society's meetings. Also, at this juncture the original enthusiasm of a large number of the less devoted members began to wane. Whereas many of them had originally desired the prestige of a Fellowship, they were not prepared to support the Society either by attending its meetings, or by paying their dues. Furthermore the social prestige of the Society was declining as the interest of the King and his court was diverted to more pressing matters such as war and politics and as more pleasant venues for intellectual discussion, especially coffee and ale houses, began to proliferate.[2] Another pernicious problem was a crippling shortage of funds due to the failure of many Fellows to pay their basic dues. By 1672 these contribution arrears

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1. Corrected numbers taken from Hunter 'Membership of the Royal Society' op.cit., figure 1. This should be compared with the earlier account in The Record of the Royal Society of London, (4th edn., London, 1940), pp.379-381, Appendix 5: 'Chronological Register of Fellows'.
2. Cf. R.Caudill 'Some Literary Evidence ... of English Virtuoso activities' op.cit., pp.367-396; other interests distracted Fellows like Glisson, Charleton, Lower, Merret and Ent after 1666. See T.M.Brown, 'The Mechanical Philosophy and the "Animal Oeconomy" - A Study in the development of English Physiology in the Seventeenth and Eighteenth Century' (Princeton. Ph.D. Thesis, 1968), pp.80-82.

had reached a total of approximately £1,818.[1] Finally, the Society exhibited an increasing lack of institutional cohesion, and began to function as 'something more like a gentleman's club.'[2] As a result it failed to push ahead with a consistent and well-defined programme for co-operative research in science or technology.[3]

However, while these internally debilitating factors greatly worried the institution's supporters (as Petty's memorandum will later illustrate) the Society also had to contend with external critics who launched an increasing number of damaging attacks. Even before the Society was officially incorporated under Royal Charter individuals were privately heaping scorn on its activities.[4] By 1664 the King himself was publicly ridiculing his offspring in a famous scene witnessed by Samuel Pepys and other courtiers:

> 'Thence to White Hall, where in the Duke's Chamber, the King came and stayed an hour or two laughing at Sir W.Petty, who was there about his boat, and at Gresham College in general. At which poor Petty was I perceive at some loss, but did argue discreetly and bear the unreasonable follies of the King's objections and other bystanders with great discretion - and offered to take odds against the King's best boates; but the King would not lay, but cried him down with words only. Gresham College he mightily laughed at, for spending time only in weighing of ayre, and doing nothing else since they sat.' 5

Whether justified or not, the attitude of the King can hardly have failed to influence fashionable opinion. For an institution which stressed the

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1. Cf. R.K.Bluhm 'Remarks on the Royal Society's Finances', 1660-1768' Notes. Recs. Roy. Soc., 13 (1958), 96.
2. For this interpretation cf. Q.Skinner 'Thomas Hobbes and the nature of the early Royal Society' The Historical J., 13 (1969), 217-239, especially 237-239.
3. Cf. Oldenburg's comments on the need for co-operative effort (c.1664) in Correspondence, ii, 320, and ibid, viii, 171 (c. July, 1671) on his hopes for an improvement in its experimental work.
4. Cf. F.S.Taylor 'An early satirical poem on the Royal Society' Notes. Recs. Roy. Soc., 5 (1947), 37-46; see also S.Butler, Hudibras (London, 1663), pp.4-6, 20-21, 126-128; Hull, Economic Writings, ii, 324.
5. Pepys, Diary, V, (1 February, 1664), 32-33.

utility of its work (as Oldenburg ceaselessly reminded his correspondents[1] and as Sprat repeatedly claimed in his History) the charge of uselessness wounded with particular effect. Thus Oldenburg could be found making a plaintive request to Wren in 1666 when plans for rebuilding London came under public scrutiny:

> 'y^t such a modell, contrived by him, and reviewed and approved by ye R.Society, or a Committee thereoff, before it had come to the view of his Majesty, would have given the Society a name, and made it popular, and availed not a little to silence those who aske continually, What have they done' [2]

This alarm at imputations of uselessness emerges strongly in the letters of Evelyn,[3] in Sprat's History[4] and in Glanvill's[5] apologia for radical natural philosophy. It was almost certainly due to this concern that Boyle published the second section of his Usefulnesse of Experimental Naturall Philosophy, in 1671.[6] However the effectiveness of these apologists, even of Boyle, in the face of bitter opposition from individual critics like Stubbe, or the disquiet or more institutionalised figures from the Universities and the Church like Barlow or South,[7]

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1. See his comments to Lubienietzki, 23 July, 1666, Correspondence, iii, 193, 'The Society is working to the end that a solid system of philosopy, truly adapted to the necessities of human life, may be constructed upon a foundation of observations and duly interpreted experiments'.
2. Oldenburg, Correspondence, iii, 231, letter to Boyle, 18 September 1666.
3. Cf. Evelyn to Cowley, 12 March, 1667 in Diary and Correspondence of Evelyn, ed., Bray, op.cit., iii, 349-350.
4. For further discussion of this polemical battle, see D.Stimson 'The critical years of the Royal Society, 1672-1703' J.Hist.Med., 2 (1947), 283-298; R.H.Syfret 'Some early reactions to the Royal Society' Notes. Recs. Roy. Soc., 7 (1950), 207-258; idem 'Some early critics of the Royal Society' ibid, 8 (1950), 20-64; Sir H.Lyons, The Royal Society (Cambridge, 1944), pp.72-115; for Sprat's History, op.cit., see introduction by Cope and Jones.
5. Glanvill devoted most of : Plus Ultra: or, the Progress and Advancement of Knowledge since the Days of Aristotle (London, 1668) to the utility of natural philosophy.
6. Usefulnesse of Experimental Philosophy, (Oxford, 1671), Cf. Fulton: Boyle Bibliography, p.41.
7. John Beale, a stalwart supporter of the Society, linked the two elements in his letter to Oldenburg of 6 August, 1671: 'It stings me, yt ye lofty pretenders to R[eligion] should abet a vilaine [i.e. Stubbe] against ye R.S. and his Majesty's everlasting honour. I thinke, I have cause to Feare yt many of ye R.S., are allmost discouraged.' Correspondence, viii, 186. For the attitudes of Barlow and South cf. Syfret, 'Early Reactions to the Royal Society,' op.cit.

seems to have been limited. As Henry Oldenburg said before the publication of Sprat's History:

> 'I must confesse, ye style is excellent, even, full, unaffected; but I know not whether there be enough said of particulars, or, to speake more truly, whether there be performances enough for a R.Society, yt hath been at work so considerable a time.' 1

Owing to the state of scientific knowledge, and the intractable problems facing contemporary natural philosophers in technologies such as applied chemistry or the agricultural sciences, there was a real, but justifiable, lack of tangible and useful discoveries. Although it has already been shown (if only in two selected areas) that this failure to produce utilitarian advances was not through lack of interest or intelligent application on the part of contemporary scientists, such a consideration would not have diminished external criticism. The consensus of opinion among modern historians such as Lloyd, Stimson and Syfret, suggests that the attempts of Sprat, Glanvill and others to publicly defend the Society against external attacks, rather than solving the problem, served only to exacerbate the situation further.[2] Nonetheless it is important to note that however violent or effective such attacks might have been, they could not ultimately threaten the existence of the institution. Only the loss of its Royal Charter[3] or (more likely) a disastrous decline in support from within, could do that. It is the latter condition which in reality provided the most serious threat to the Society's well-being.

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1. Oldenburg to Boyle 24 November, 1664. cf, Correspondence, ii, 321.
2. Oldenburg's reluctance to mention this criticism in 1667 changed to an impassioned attack on the Society's opponents by 1671. Cf. dedicatory letter to Brouncker in Philosophical Transactions, Vol.2. (1667-1668), and Preface, ibid, Vol.6 (1671), 2088-2093.
3. Royal support was seen as the cornerstone of the Society's existence. Cf. John Newburghe to Oldenburg 9 August, 1670 in Correspondence, vii, 106.

(b) Crisis and Response 1673-1675

As early as 1670 Henry Stubbe had identified this condition as the Achilles heel of the Society, and had tried to exploit the situation by enlarging on the weakness:

> 'Nay, He [the King] hath herein been Exemplary to his Subjects, by withdrawing much of his Encouragements, and testifying frequently his disesteem of these Experimental Philosophers. Thus many of the Nobility, most of the Physicians and other understanding and serious persons have either totally deserted the Society or discontinued their presence at their Assemblies. And I could wish they would not abuse the world with false Catalogues, but give us a true one of such men as do not frequent their meetings, keep correspondence with them, and pay the usual contribution.' [1]

Stubbe was certainly wrong about the correspondence of the Society, which was as extensive as ever, and in his implication that its reputation was subject to a universal decline: this was ironically true at home, but abroad it continued to command the highest respect from almost all interested parties.[2] Nevertheless while Stubbe often, though not always,[3] spoiled his own case by exaggeration and excess, in this particular instance his question was both perceptive and potentially damaging, for it highlighted the crucial, cancerous element which could prove fatal to the ailing corporation.

In the light of the above evidence Petty's brief assessment of the moribund condition of the Society, far from appearing anomalous, seems to have been a sober and well-judged reaction to the situation in August, 1673.

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1. H.Stubbe, Legends no Histories or ... Animadversions upon ... the Royal Society (London, 1670), preface (unsignalled).
2. Ibid, preface, for Stubbes' disparagement of the Society's foreign reputation, which should be compared with the adulatory letters in Oldenburg, Correspondence, ii, 65-67; ibid, viii, 448-449 and 558-561; see also ibid, X, xxii-xxiii.
3. Legends no Histories, was often extreme, but not necessarily incorrect. Thus Stubbes' criticism of Henshawe's 'History of ... Salt Petre' (printed in Sprat's History, pp.260-283) was erudite and effective. Cf. Legends, op.cit., pp.35-127.

As an observer freshly returned to the scene after a prolonged absence, he could perhaps distinguish more clearly the true extent of the decline. In fact by the end of the year the contribution arrears had risen to £2,114.[1] In the middle of the summer the President had again been forced to order a formal recess[2] while at the same time trying to ensure that informal meetings continued in the capital. This followed a number of occasions earlier in the year when regular meetings had not been held owing to the lack of a quorum.[3] During the period up to the end of September the recruitment of new Fellows had again been low.[4] Thus, despite the exhortation of some Fellows that the Society should pursue a forceful and united policy of self-help,[5] and the ineffective attempts of the Council to follow this advice,[6] the situation had clearly reached a critical state by mid October, 1673. At this point Sir William, whose growing involvement in the crisis led to increasingly frequent and energetic participation in the Society's affairs,[7] joined with other leading fellows to promote firm remedial action.

This took the form of an attack on three crucial areas: the lack of working funds, low attendance figures, and the paucity of material and experiments presented at regular meetings. With regard to the financial status of the Society, it was decided that the exact total of each

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1. R.K.Bhatia, op.cit. 96, 'Table 5.'
2. This recess, first called on 10 July, 1672, cf. Birch; History, iii, 37, was again instituted between 13 June and 9 October, 1673, cf. ibid, 92-93.
3. For example no meetings took place on 26 February or 30 April. cf. ibid, 77 and 85.
4. Between January and September, 1673, only three new Fellows had been elected. cf. Record of the Royal Society, op.cit., p.382; Hunter, 'Membership of the Royal Society' op.cit., 'Fellows of the Royal Society'
5. Cf. Beale's comments to Oldenburg on the need for united action, Correspondence, vii, 440 (c.1671) and ibid, viii, 186.
6. For the failure of the Council's policies, cf. Birch, History iii, 63 & 70
7. Using the entries of Petty's name in Birch History as an indication of his participation, a close scrutiny of G.E.Scala: 'An Index of Proper Names in Thomas Birch, The History of The Royal Society, (London, 1756-1757),' Notes.Recs.Roy.Soc., 28 (1974), 263-329, reveals that Petty became inextricably linked with the Society between 1673 and 1675.

Fellow's arrears should be ascertained and that he should be requested to pay them within a certain period.[1] To that end a committee, which included Sir William, was eventually set up on 22 December to enforce this decision. It was also called upon to obtain the signatures of as many Fellows as possible to the newly-proposed bond guaranteeing future attendance and payment of dues.[2] On the 5 January, 1674, at the request of the Council, David Colwall, Treasurer of the Society, made Petty directly responsible for the collection of this money.[3] Meanwhile, Sir William sat on another newly-created committee which had been given the task of organising a programme of experiments to be undertaken at future meetings of the Society.[4] On 27 November, Petty's leading role in this attempted revival was recognised by his election to the Council, along with other Fellows such as Southwell and Cutler.[5] Then on 22 January, 1674 his influence was enhanced still further when Brouncker nominated him as his acting deputy in the office of President.[6]

Unfortunately, this response to the crisis proved to be inconstant and short-lived. Within a few months the register indicates that the Society's meetings were again either thinly attended or did not take place at all.[7] The recruitment of new members, which had shown a marked increase at the end of 1673, soon died away to the previously insignificant level,[8] also the 'Summer' recess called after a few de-

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1. Cf. Birch, History, iii, 94-95, 100.
2. Ibid, 113. The text of the bond is at ibid, 108-109.
3. Barlow (the artist) was first chosen, but refused this onerous task. Cf. ibid, 142-143; Petty was then designated, and accepted. B.H. MSS. 37, Box H, folder 2, ii, d, e, g, j, k, constitute lists, statutes etc., relating to Petty's work. See also Birch, History, iii, 120, 127, 129.
4. Cf. ibid, 119; other members were Boyle, Wren, Goddard, Grew and Hooke.
5. Ibid, 112-113.
6. Copy of Brouncker's order at B.H. MSS. 37, Box H, ii, d; see also Birch, History, iii, 123.
7. Cf. ibid, 120, 122, 129, 132, 134 and 135.
8. Between 6 November and 11 December, 1673 ten Fellows were elected. In the period January to December, 1674 only five Fellows were registered. See Record of the Royal Society, op.cit., p.382. Hunter 'Membership' op.cit., 'Fellows ... 1660-1685'.

sultory meetings, lasted from June to November.[1] Altogether this period marks the nadir of the Society's fortunes during the first two decades of its existence, a continuing state of affairs fully recognised by Petty in his letter to Sir Henry Ford of October, 1674:

> 'Gresham Colledge being almost sunk wee are now endeavouring to restore it if possible to its due vigour and efficacy.' 2

Whatever the cause of this situation (the dislocating effect of the third Anglo-Dutch war, or a combination of other factors[3] already outlined) the Society was at its lowest ebb in the Autumn of 1674, and vigorous efforts were needed to ensure its survival.

It was during the summer of 1674 that Petty initiated the first moves in this campaign of resuscitation. Presiding over two Council meetings[4] in the absence of the ailing Viscount Brouncker, he outlined yet again the major problems facing the institution, and the obvious course of action which they dictated:

> 'Sir William Petty proposed, that there might be drawn up some thing, that might effectually tend to put new vigour into the meetings of the Society, and to bring in the arrears, by representing, that the council having considered the present condition of the Society, arising from the want of good experimental entertainment at their meetings, and from the neglect of the members in paying their weekly contribution, had thought it necessary to fix a certain number of Fellows, able and willing to entertain the Society every week with a considerable experimental discourse; and for the defraying of the expence necessary for the making of experiments, to appoint a Solicitor to call in their arrears, and to acquaint such as [are] in arrears with the obligation, which they had subscribed to upon their admission, and with the Society's intention of proceeding to a legal recovery of their arrears against such, as should refuse or delay the payment thereof.' 5

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1. Birch, History, iii, 135 and 138.
2. B.H. MSS. 19, pp.301-302; Petty to Sir Henry Ford, 13 October, 1674.
3. The arrears of contributions proved particularly difficult to collect and many Fellows advanced dishonest excuses to avoid payment; little money was forthcoming, cf., Birch, History, iii, 127-128.
4. The meetings took place on 27 August and 29 September. See ibid., 136.
5. Ibid, 136.

Here, with Petty virtually in sole command of operations, the Council appeared ready for the first time to adopt a stringent and determined policy. This serious threat of legal action, which was later to prove unacceptable to the more timorous or socially-conservative Fellows, is clearly stamped by Petty's idiosyncratic and radical attitudes. It did not concern him whether the recalcitrant Fellow was a duke or a tradesman: if he had freely signed a legally binding agreement, he was liable to prosecution whatever his social status. This uncompromisingly direct approach, (so characteristic of his early view of the corrupt state of Gresham College, or of the unproductive nature of some systems of natural philosophy)[1] is also a major feature of Petty's unpublished analysis of the Society's decline in 1674. Asked to draw up a 'declaration' describing the crisis and outlining a scheme for the reduction of the Society's membership[2] to Fellows seriously interested in experimental natural philosophy and willing to pay their dues, Petty produced an unequivocally realistic memorandum. The culprits, causes and remedies were all clearly delineated with a penetration and logic which disregarded social and political niceties. Sir William's main intention was nothing less than to change the fundamental character of the Society: he hoped to direct it away from its empty role as a club for gentlemen or as a sounding board for the research and opinions of miscellaneous individuals, back towards the pristine view of 'Solomon's House.' By cutting out the dead wood of Fellows who, through inactivity or malice, now weighed so heavily on the institution, the remaining enthusiasts would be allowed to resurrect that dynamic vision of co-operative research which had inspired the early years of the Society.[3]

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1. See Chapter 2, p. 219 and p.220 above, and Appendix III, i, below.
2. Birch, History, iii, 136-137.
3. For the full text see Appendix III, section i. This is Petty's original draft which was 'toned down' at successive Council meetings and blended with another 'declaration' by Goddard. cf. Birch, History, iii, 137, meeting of 15 October.

On financial and administrative affairs the Society first proceeded at a moderate pace once the summer recess was over. It was ordered that the Statute allowing outside attendance of meetings was to be rescinded;[1] in addition all Fellows were admonished not to divulge the Society's affairs to non-members, thereby avoiding the circulation of unofficial and critical reports. By November plans for a new form of subscription[2] and the joint 'declaration' of Goddard and Petty had both been sent to the printers.[3] By the end of January 1675,[4] once it was clear that sixty Fellows were prepared to sign the more vigorous bond, copies of the amended declaration were sent out with covering letters to all the Fellows who were in arrears.

Nevertheless, despite these efforts, the initial impetus for financial retrenchment seems rapidly to have run down, owing no doubt to the enormous difficulty of collecting the money, to a differing view of the Society's proper function, and to a debilitating fear of the social opprobrium which would result were the Society to initiate legal proceedings enforcing payment or ejection. As a result, the arrears continued to increase,[5] and Petty's tough, sensible policy was allowed to lapse, with only a few token ejections being made.[6] Thus, although the Society's basic income may have marginally increased over the next few years due to more regular subscriptions from those Fellows who had signed the new bond, in general it remained very short of funds.

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1. Ibid, 137-138.
2. Ibid, 140-141 and 142-143 for a copy of the Statute incorporating this new legal bond.
3. Ibid, 137, 138, 139, 140, 155. No copies of the printed declaration have yet been traced.
4. Ibid, 176, 177, 178 and R.K.Bluhm, op.cit., 97.
5. Cf. Ibid, 96, 'Table 5: Arrears of Contributions, 1663-1687'. In 1675 the arrears totalled £2,584. For the problems of collection, and evasion of payment, cf. Birch, History, iii, 191.
6. See Birch, History, iii, 228, 231, 233 and 243 for the details of this action.

This failure to pursue a vigorous policy of legal action coupled with a reduction of membership, probably annoyed Sir William and may help to explain why his attendance at the Society rapidly declined during 1675[1] and early 1676. Such timidity was abhorrent to Petty with his vision of a vigorous community involved in co-operative and useful research. Ultimately, he would have regarded any lack of conviction on the part of the Society's leaders with a view that combined disillusionment with ill-concealed dismay. The Society as it existed in 1675 was totally different from the government-backed research institute that Petty had described in the Advice (1648), and which continued to influence his attitudes thirty years later. It lacked the essential State support, both political and financial, that alone would have given it the power to reconstruct society. Sir William compared this unfavourably with its counterpart in France, and may well have made such a comparison more forcefully when giving private advice to the Council.[2] In the final analysis Petty's viewpoint (like that of John Beale) was in conflict with the political and social ethos of Restoration England, and his picture of the correct structure and function of the Royal Society, like his attitude to the role of government, inevitably isolated him from those who found the

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1. When the Society reconvened after the summer recess Petty did not attend with the same frequency. Even when directly requested to do so by the President and Secretary he omitted to support the Society. For this, see Birch, History, iii, 243-244. See also Scala, op.cit., 311 for the frequency of Petty's recorded participation in Society meetings.
2. An anonymous memorandum, 'Proposals for the Advancmt of the R.Soc', seems to bear the imprint of Petty's direct and unsentimental style. It is at Royal Society MSS. D.M.5. 12. While there is no conclusive evidence, it probably dates from 1673 to 1674, and was written by Petty, or another Fellow with similar attitudes, to point up the unfortunate difference between the Society and Academie des Sciences.

> 'The R.S. was begun and is continued at least alive by the Voluntary Contributions and as voluntary labours of the Members.
>
> The Parisian consists of select Members all Pensioners paid for what they do their Tasks set and due performance expected with at least a Philosophical Scandal on the lazy and negligent.
>
> If the members of the R.S. do nothing seldome come to Meetings and when they come tis only as to play to amuse themselves for an hour or so, tho they never think of promoting the Ends of the Institution, yet if they pay their Contributions which by their subscriptions they are unavoidably obliged to do, they take themselves to be (and indeed in respect of those who scandalously refuse payment are) good Members.'

current environment more congenial. Nevertheless his stringent proposals were the only course of action which might have guaranteed the future strength of the institution. Despite the rise in its fortunes over the next few years, when better recruitment,[1] and the brilliant work of absent individuals like Newton or Leeuwenhoek, added a stimulus and lustre to its proceedings,[2] financial insolvency, the death of Fellows such as Oldenburg and Goddard[3] and political disruptions at the end of the decade meant that the Society inevitably tottered towards another crisis in 1680.[4]

However, if the Society failed to endorse Petty's programme for reform, it was much more enthusiastic about his proposals to increase the number, and improve the quality, of papers and experiments given at its regular weekly meetings. As we have seen, Sir William had been asked in December, 1673 to take 'particular care' over the organisation of a revitalised programme of 'considerable experiments'. In October, 1674 he revived this motion, with a firm proposal that a rota of Fellows 'able and willing' to give 'a considerable experimental discourse' at each meeting should be compiled on a reliable but voluntary basis. This return to an organised, co-operative structure seemed to him the only course which would guarantee the experimental vitality of the Society, and relegate to the past the ineffective meetings at which insub-

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1. The Society was able to elect some outstanding Fellows between 1674 and 1679 such as Grew, Flamsteed, Plot, Halley and Houghton. Cf. Record ... Royal Society, op.cit., pp.382-383.
2. For basic information on Newton (F.R.S. 1672) cf. Birch, History, iii, 247-318 (letters and papers on light etc.,); A.R.Hall, Galileo to Newton, op.cit., pp.262-269 (references to Newton on optics, and secondary materials). For Leeuwenhoek (F.R.S. 1680) see C.Dobell, Antony Van Leeuwenhoek and his "Little Animals", (London, 1932), especially pp.52-55; The Collected Letters of ... Leewenhoek (Amsterdam, 1939-1967); Philosophical Transactions, cxxxiii (25 March, 1677), 821-823, letter on discovery of animalcules; F.J.Cole 'Microscopic Science in Holland in the Seventeenth Century' J.Quekett Microscopical Club, 1 (1938), 1-20.
3. For Goddard's biography cf. Hartley, The Royal Society, op.cit., and Birch, History, iii, 244-246.
4. Evelyn's comments in the third edition of Sylva, or a Discourse of Forest-Trees (London, 1679), Introduction Sig A1 to end, provide strong evidence of this decline.

stantial papers or experiments were discussed on an irregular, ad. hoc. basis. In addition, during the last few months of 1674, he called again for the reorganisation and repair of the Society's scientific instruments and apparatus,[1] and for a restructuring of the register of papers presented at the Society.[2] As a result of these proposals the Council delegated Sir William to produce a 'declaration' calling for volunteers to contribute to the programme of experimental papers, and later he followed this up with two separate letters to all the Fellows asking for their direct support over the measure.[3] Consequently, a list of such contributors was organised on three subsequent occasions, and this carried the Society's programme through until the summer recess.[4]

The immediate result of this activity was a marked and gratifying improvement in the quality of scientific work presented at the Society's weekly gatherings. The first three discourses were given by Wallis, Boyle and Petty, and these (as the table indicates),[5] were followed until July, 1675 by a fairly regular sequence of papers and experiments of a similar nature. These discourses cover a wide range of current scientific and technological interests and this period of activity illustrates well the character of the Society's involvement with contemporary natural philosophy. They include subjects as diverse as theoretical physics, chemistry and botany, balanced by papers on the utilitarian applications of mathematics or soil science. In comparison, the eight months between November 1673 and July 1674, filled with days when the Society failed to meet, or when it worked at a disjointed and incohate level, seem to belong

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1. Petty first suggested this in December, 1673. cf. Birch, History, iii, 115, and ibid, 159 for its revival.
2. 'Memorandum, that it was propounded by ... Petty, that all the discourses entered into the Society's Register-books should be divided into several sections and chapters'. ibid, 159.
3. Ibid, 139 and 162.
4. Ibid, 137, 160, 175.
5. See Appendix III, ii.

to a different era of decay and crisis. Another developing feature of the months before and after Christmas, 1674 was the growth of the Society's official programme for the publication of work presented at its meetings. Whereas only one discourse was published by official order between October 1673 and October 1674,[1] at least eleven papers received this official sanction over the next twelve months.[2] While these did not all appear immediately, there is no doubt that in conjunction with the Philosophical Transactions, a substantial body of work representing the Royal Society's views and proceedings emerged as a deliberate counter-weight to the calumnies of its critics.

Another important element which this episode illustrates is the fact that this revival was engineered and maintained by a limited group of members who gave the Society's work its character and resilience. Although Petty was one of the first to provide material for the meetings, it is quite clear that the later part of the programme was more regularly sustained by Fellows such as Hooke, Boyle and Grew.[3] As always Henry Oldenburg, the indefatigable secretary, carried out his epistolary duties on a vast scale, and published the Philosophical Transactions with an invariably perceptive editorial eye.[4] These facts (reinforcing as they do the opinions of some recent historians and contradicting those of others[5]) when coupled with the evidence presented by Petty in his

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1. Cf. Birch, History, iii, 132. Oldenburg read a discourse by Dr. Coxe 'concerning his way of extracting volatile salts' on 26 March, 1674, which was 'much applauded' and ordered to be printed 'forthwith'; cf. Philosophical Transactions, ci, (25 March, 1674) 4-8.
2. Cf. Appendix III, ii, column five, for those papers sanctioned for official publication.
3. In the year ending November, 1675, three discourses by Boyle, and five each by Grew and Hooke were presented at the Society's meetings.
4. For the editorial quality of the Transactions, see Layton, 'The Popularisation of Science in Great Britain, 1650-1800' (M.Sc.Dissertation, University of London, 1955), especially pp.54-56. Layton maintains that in comparison with the Journal des Scavans or other collections, Oldenburg produced a journal 'severely edited for scientific content' which made a 'solid contribution to the advance of Science'. See also: E.N. da C.Andrade, 'The Birth and Early Days of the Philosophical Transactions' Notes Recs.Roy.Soc., 20 (1965), 9-27.
5. See: The Intellectual Revolution of the Seventeenth Century, ed., Webster (London, 1974), Introduction, pp.20-21, which questions the validity of the statistically-based opinions in L.Mulligan 'Civil War politicis, religion and the Royal Society' ibid, pp.317-346.

unpublished memorandum, help to highlight the truth that the Society's work and fortunes were not maintained by the total membership, but by a limited and moderately constant group who formed its 'active nucleus'.[1]

However, the vitality and organisation of this movement, as well as the efforts for financial retrenchment, began to diminish as the year went on. After the summer recess the administration of the programme was allowed to lapse and this undermined the regular delivery of papers on predetermined topics by an organised system of volunteers.[2] Almost certainly this development was an integral part of the same set of factors which weakened the Society's communal resolve to take firm legal action over the questions of membership and collection of arrears. Although the general tenor of activity at Society meetings did not drop to the alarmingly low levels of 1673 to 1674, it did for at least five years resume the old irregular pattern of ad. hoc. discussion and experiment. Despite the stimulating work of correspondents like Newton and Leeuwenhoek, the Society once again failed to develop a self-fuelling dynamic based on enthusiastic co-operation, such as would have enabled it to pursue research programmes in a forceful way and withstand external and internal pressures leading towards decay and dissolution.

It was also this lack of resolve, and this tendency to revert to a congerie of interested individuals, that probably annoyed Petty, and caused him to limit his involvement with the Society.[3] This would explain why, in November 1675, he failed to respond to two direct pleas for help. In the first, the President asked Petty to provide a further paper at one of the weekly meetings:

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1. This group did change as the years progressed. For a detailed analysis cf. Hunter 'Membership of the Royal Society' op.cit., which shows the effects of new Fellows on this important nucleus.
2. For evidence of this decline see below, Appendix III, ii.
3. For Petty's later relationship with the Society, see above, Chapter 1, pp.189-192. Although elected to the Council in 1679, 1682 and 1687 he never devoted the same time or energy to the Society's affairs.

'Sir,

The Concerne I have for the Good of the Royal Society, obliges me to desire you would give them a second Entertainment upon that Excellent Subject, so ingenuously by you begun, of Elasticity, and to doe this upon the 11th November next, when wee shall be destitute of a Lecturer. This will certainly be an acceptable Service to the said Society and a favour to, Sir, Your humble, affectionate servant,

Brouncker.

You may be pleased to remember that the time your selfe had chosen for your lecture was the third meeting after our Recess; which happens to be the said 11th of the next month.' 1

In the second letter, the Secretary plaintively importuned Sir William to respond favourably to the President's earlier request:

'Sir, November 10, 1675.

Since I am not so fortunate as to find you to be spoken with at home, I must discharge my duty to ye R.Society in writing wch obliges me at present to signify to you, yt My Ld. Brouncker having, as he told me, sent you a letter last week, to put you in mind of giving ye Society ye 2d part of yr former Discourse tomorrow, if possible, his Ld shipp desired me to sollicite you, yt you would not faile to comply with ye import of his letter, there being nobody else to read tomorrow, and ye Company relying upon you for your performence. Sir, the approach of our Anniversary Election makes us ye more earnest in having our Assemblies well filled and pleased before ye said day; to which you are able to contribute much, if you please, in the persuasion of Sir, your very humble and faithful servt, H.Oldenburg.

Tomorrow there will be also a Council about noon where yr presence will be very necessary. Pray bring Sir James Shaen and Sir R.Southwell with you. Pray Sir, send me a word or two in answer of this, yt we may know what to trust to.' 2

In spite of these direct appeals the records show[3] that Sir William

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1. B.H. MSS.6, Section 3, Letter 71. A provisional dating of 3 November, 1675 is suggested by comments from the following letter.
2. Ibid, Section 3, Letter 73.
3. Birch, History, iii, 230-231.

did not deliver the sequel to his earlier discourse at the next meeting on 11 November, 1675. Instead he seems to have withdrawn himself almost completely from the Society's activities, attending the meetings only twice between October and his departure to Ireland after February 1676.[1] In this context it is significant that he was not re-elected to the Council on 30 November, 1675.[2] However, it is also significant that Brouncker urged him to continue his earlier paper and, by implication, his enthusiastic support of the institution. For the published Discourse of Duplicate Proportion clearly outlined many of the intentions and circumstances of the Royal Society which has continued as the book's most valuable function from Brouncker's time until the present day.

(c) The Discourse anatomised

The 12 mo treatise runs to over one hundred and sixty pages.[3] Prefacing the work are two dedicatory letters, one to William Cavendish, Duke of Newcastle, and the other to Brouncker, as President of the Royal Society. The central body of the text consists of a twenty-page introduction, followed by the main argument, in which Petty describes and exemplifies his application of the mathematical formula of 'duplicate proportion'. This central hundred pages is divided into eighteen sections or 'Instances'. The work is completed by a short 'Appendix of Elasticity' and a brief conclusion.

The motivations underlying Petty's composition and publication of the treatise are outlined in two preliminary letters and the introductory chapter. In the first letter he dedicates the work to Cavendish because it concerns methods and interests that were current in Paris when they were associated there during 1645 and 1646:

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1. Ibid, 242 and 308 for Petty's attendance at the meetings of 29 November, 1675 and 24 February, 1676.
2. Ibid, 244.
3. For a more extensive delineation of the contents of the treatise see Appendix III, iii.

> '... your Grace doth not onely love the search of Truth, but did encourage me 30 years ago as to Enquiries of this kind. For about that time, in Paris, Mersennus, Gassendy, Mr. Hobs, Monsieur Des Cartes, Monsieur Roberval, Monsieur Mydorge, and other famous men, all frequenting, and caressed by, your Grace and your memorable Brother, Sir Charles Cavendish, did countenance and influence my Studies, as well by their Conversation as their Publick Lectures and Writings : Much of which honours and helps I owe unto your Grace, and have a fresh remembrance of them'. 1

As later analysis will show this account is entirely accurate with regard to the origin of many of the topics covered in the treatise. Petty also reports, with self-deprecating honesty, his own failure to advance these problems:

> '... there is a contrary reason, why it [the treatise] should have wholly Shun'd your Graces sight and knowledg: which is, That your Grace might not perceive hos little progress I have made in thirty years time upon those Studies ...' 2

yet he hopes that his publication of the book will show: 'that no heterogenous Cares and Troubles have or can quench my affections to Philosophy'.

The introductory sections are primarily concerned with an officially sanctioned defence of the aims, work and circumstances of the Royal Society. The institution's activities, Petty maintains, have a three-fold purpose. First, it hopes to explain the meaning and characteristics of basic phenomena in nature, or:

> '... The Intricate Notions, or Philosophia Prima of Place, Time, Motion, Elasticity etc. in a way which the meanest Member of adult Mankind is capable of understanding:' 3

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1. Petty, Discourse, 'The Epistle Dedicatory,' Sig. A8v-A9v.
2. Ibid, Sig.A 12r - a.l.r.
3. Ibid, Sig. A4r + v.

Later in the first chapter Petty himself gives a 'Dictionary', or explanatory list of sixteen abstract terms, such as 'Place', 'Proportion', or 'Figure', which he thinks will occur repeatedly throughout the treatise.[1] In doing so, he hopes to establish his personal definition of these words so that a clear and consistent meaning is guaranteed for this and other future works. The second purpose of the Society and of the Discourse, is:

> 'to consider such points and properties, even in Atoms (such, whereof perhaps a Million do not make up one visible Corpusculum) as may give an intelligible Account of the Nexures, Mixtures, and Mobilities of all the parts of the Universe.' 2

In this aspect, then, the treatise was firmly immersed in the current debate about the mechanisms of nature, and whether these were based on corpuscular, atomistic or infinitely reducible particles. Later in the book, Petty describes in some detail his own version of the atomistic philosophy, an exposition which was to prove one of the most controversial elements of the treatise. Probably the most important function of the work is:

> '... to excite the World to the Study of a little Mathematicks, by shewing the use of the Duplicate Proportion in some of the most weighty of Humane affairs, which Notion a Child of 12 years old may learn in an hour: ...' 3

Thus he deliberately refers in the second dedicatory epistle to Graunt's Observations on the Bills of Mortality as an example both of literary procedure and, by implication, of correct intellectual orientation.[4]

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1. Ibid, pp.12-17. The list includes: Matter, Body, Figure, Place, Motion, Quantity, Quality, Habit, Time, Proportion, Weight, Swiftness, Force and Elasticity.
2. Ibid, Sig. A5r + v.
3. Ibid, Sig. A4v - A5r.
4. See letter to Brouncker, Discourse, Sig. a.2 r + v. Graunt's work best exemplified the application of 'little small threds of Mathematicks to vast uses,' ibid, Sig. A.6.r.

Finally, Petty has a particular educational candidate in mind, whom he thinks might benefit from the mathematical method outlined in the treatise; this youth is named as Cavendish's grandson, the eldest child of Lord Ogle, a personal friend and political patron of the author.[1]

In alluding to the crisis faced by the Royal Society during the last months of 1674, the published work makes only a few guarded remarks:

> 'Forasmuch as this Society has been censured (though without much cause for spending too much time in matters not directly tending to profit and palpable Advantages (as the Weighing of Air and the like) I have therefore, to streighten this crooked stick, bent it and my present Discourse the quite contrary way, viz. to the Sails and Shapes of Ships; to Carpentry and Carriages; to Mills, Mill-dams, Bulwarks; to the Labour of Horses, and to several other particulars:' 2

It is of great significance that the printed version of the treatise omits an important prologue of over 350 words which spells out in clear and rousing language the dire problems facing the Society.[3] Equally, this prologue indicates that Petty did not regard his contribution to the Society's programme as anything more than a pilot study, a short essay which was hurried, polemical and incomplete.[4] A statement contained in both manuscript and printed versions provides a further explanation of this characteristic, so typical of many of Petty's published works:

> 'The which [examples of duplicate proportion] are not only gross enough of themselves, but are also as grossly handled in this Exercise, to prevent the further imputation of needless Nicity, and to leave room for your own further thoughts upon the same.' 5

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1. Cf. Petty to Ogle, B.H. MSS.6, Section 3, Letter 18, where he asks him to intercede with the Lord Treasurer, Lord Bridgewater, and the King. When Petty wrote this letter on 9 July, 1674, he was negotiating about tax concerns in Ireland.
2. Petty, Discourse, pp.1-2.
3. See the transcript of this in Appendix III, iv.
4. Ibid, final paragraph.
5. Petty, Discourse, pp.2-3. Few of Petty's books were composed with publication in mind and those that were, reflected more a concern for immediate effect, than orderly and meticulous preparation. On the uncorrected mistakes in Petty's printed works cf. Hull, Economic Writings, op.cit., i, lviii-lix and Lansdowne, Petty Papers, 1, xxii-xxvi. The Discourse was essayistic in tone and disorganised in expression.

The excision of this prologue from the published text is readily understandable. When he originally delivered the Discourse as a lecture, Petty was given the opportunity to make yet another public appraisal of the Society's true condition, and to demand more wholehearted support. Consequently this appraisal outlined the current crisis and the necessary response in the most grave and emphatic terms, and while such realism aided the process of evaluation and planning its publication could only harm the Society's reputation.

Another significant feature of the Discourse is that it shares a number of characteristics with other works which appeared as part of the Society's programme of 1674 and 1675. For example, the diminutive format of this book was adopted for the second in the series, Grew's Discourse of Mixtures.[1] At this stage the Society's criteria for publication, prompted by a desire for maximum publicity, probably demanded a low price for production and purchase. Also, at least three of the works deliberately included in their titles the fact that they originated from papers delivered at regular meetings of the Society.[2] A further similarity, and one that will be investigated later, is that many of these discourses expressed concern over the question of atomism. Other features often present in a subdued form are an awareness of the individual's role in this corporate programme, combined with a restatement of the purpose, nature and royal links of the Society, and a desire to go directly to the evidence of experience and experiment, thereby avoiding empty quibbles over 'more forms' or words.

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1. N.Grew: A Discourse Made before the Royal Society, December 10 1674. Concerning the Nature, Causes, and Power of Mixture, (London, 1675). At least one more discourse was published in this format: Nathaniel Henshaw: Aero-Chalinos; or, A Register for the Air, (London, 1677).
2. Those of Wallis, Grew and Petty shared this feature. The full title of Petty's work is: The Discourse Made before the Royal Society the 26. of November, 1674. Concerning the Use of Duplicate Proportion in sundry Important Particulars : Together With a New Hypothesis of Springing or Elastique Motions. The full title of the Wallis tract is: A Discourse of Gravity and Gravitation grounded on Experimental Observation Presented to the Royal Society 12 November, 1674,(London, 1675).

Given this framework of historical circumstance, intellectual motivation and shared characteristics, it is now necessary to examine the method and content of the work, about which Petty noted:

> 'I am commanded by the Royal Society to Print the Discourse, which I made before them, upon the last Meeting-day of their last year ... Because ... the Society are content, that this Exercise pass for a Sample, pro tanto, of what they are doing;' 1

(d) Mathematics and Method in the Seventeenth Century

The predominant intellectual axis of the Discourse of Duplicate Proportion is mathematical, and as such it reflects one of the cardinal developments within the seventeenth century: the explosive growth of sophisticated mathematical knowledge and the widespread triumph of the belief in mathematical reasoning as a most productive method for the analysis of natural phenomena. The classic confirmation of this potentiality can be seen in the rapid acceptance, by those with sufficient mathematical skill, of the Newtonian synthesis. For these cognoscenti Newton's work seemed by 1700 to embody the most persuasive and influential paradigm of correct scientific methodology.[2] Yet even the most cursory examination of Petty's Discourse and Newton's Principia shows how diverse the nature, level and intended function of two mathematical works could be during this period. It illustrates the fact that mathematics meant many different things to different people, and that there were no clearly defined standards or rigid schools of mathematical thought. Thus to understand Petty's approach to mathematics, or indeed that of Newton, it is necessary to analyse the subject's basic educational experience within the variegated context of contemporary mathematical

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1. Petty: Discourse, Sig. A3v - A4r.
2. In Structure of Scientific Revolutions, (Chicago, 1964), pp.12-14, T.S.Kuhn makes the extreme statement that Newton's work in optics and gravitational theory must be regarded as the first classic paradigm in the history of science. This should be compared with Dijksterhuis, Mechanisation of the World Picture, op.cit., p.408, on the universality of the Cartesian and Aristotelian systems. Cf. ibid, pp.405-407 for an exemplary discussion of the mathematization of science in the seventeenth century.

knowledge.

Recent work on the development of mathematics in the sixteenth and seventeenth centuries has helped to establish that despite many individual variations, the work of contemporary mathematical practitioners can be sorted into six broad but distinct categories: the classical geometers, the cossist algebraists, the applied mathematicians, the mystics, the artists and artisans, and the analysts.[1] The tradition of classical geometry was associated with Renaissance humanism and largely shared its Italian and French locale. It included within its ranks the figures of Frederigo Commandino (1509-1572), Gianalfonso Borelli (1608-1679) and Galileo. The works of these authors made no reference to current algebraic research and accepted the canons of the Platonic and Aristotelian philosophies of mathematics: namely the strict separation of arithmetic and geometry, the essential rigor and demonstrative superiority of geometrical method, and the reduction of mathematics (and even physics) to geometrical principles in the Greek style.

On the other hand the tradition of cossist algebra (primarily German and Italian, and,unlike the geometers,operating mainly outside the precincts of the university) placed emphasis less on style than on innovation in the solution of problems.[2] As inheritors of Arabic and and Babylonian techniques of algebra, the cossists developed methods which were essentially a sophisticated form of arithmetical problem-solving,

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1. See M.J.Mahoney, The Mathematical Career of Pierre de Fermat (1601-1665), (Princeton, New Jersey, 1973), which has an historical awareness unusual in works on the history of mathematics, and has provided invaluable guidance for the present synopsis. See especially pp.1-57 and 348-355. Other standard reference works include: Sir T.Heath: A History of Greek Mathematics,(2 Vols, Oxford, 1921); D.E.Smith: History of Mathematic (2 Vols, London, 1925); J.F.Scott: A History of Mathematics, from Antiquity to the Nineteenth Century, (London, 1958) referred to subsequently as, 'Scott: History'; The Mathematical Work of John Wallis, D.D. F.R.S. (1616-1703), (London, 1938), 'Scott: Wallis'. See also, K.T.Hoppen, The Common Scientist, op.cit., pp.117-123, 'Mathematics'.
2. The ranks of the cossists include Rudolff, Cardano, and Clavius. Their principal works on cossist algebra appeared in 1525, 1545 and 1608 respectively.

often applying these to the increasingly complex procedures of an expanding European commercial world. However, despite this strong interest in the practical aspects of commercial mathematics, they created a literature for fellow specialists without any overt educational intent. In addition the competitive relationship which existed between these practitioners, who often depended on their mathematical skill as a means of livelihood, lent the cossists a style of exposition and an attitude to publication which was unique.

Whereas the applied mathematicians shared the practical, problem-solving orientation of this group, they usually adopted a less competitive, and hence less secretive, approach to their activities. Applied mathematicians of this type were to be found throughout Europe in the seventeenth century, but it is true to say that they were probably most numerous, and had developed the richest tradition, in England and the Low Countries.[1] They generally shared a belief that possession of the relevant mathematical skills brought the practitioner only half way towards the solution of his problems. The development of accurate navigational techniques, the establishment of more exact maps and charts, improved methods of land surveying and land drainage, the design of canals and fortifications and the practical development of ballistics - all required an experience and ingenuity which transcended mathematics. Their written work revealed an eclectic attitude towards sources, and they utilised both the methods of classical geometers, like Euclid and Archimedes, and procedures derived from the developments of cossist algebra.

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1. Cf. Taylor, Mathematical Practitioners, passim; Webster, Instauration, especially 349-350; Hill, Intellectual Origins, passim.
2. A good example of this is the work of Stevin, the brilliant Dutch engineer, natural philosopher and mathematician. See E.J.Dijksterhuis: Simon Stevin, Science in the Netherlands around 1600, (The Hague, 1970); G.Sarton, 'Simon Stevin of Bruges (1548-1620)' Isis, 21 (1934), 241-303 and ibid, 23 (1935), 153-244; O. ten. Have: 'Simon Stevin of Bruges', i A.C.Littleton and B.S.Yamey: Studies in the History of Accounting, (London, 1956), pp.236-246; R.J.Forbes: 'Simon Stevin, Engineer', Actes du 8me Congres International d'Histoire des Sciences, 3, (1956), 935-939; Webster, Instauration, pp.412-420 for the development by Wood of Stevin's ideas on decimalisation.

The result was the production of techniques which sacrificed theoretical rigor in the interests of successful application to new or existing problems. The same utilitarian spirit overrode the classical Greek dichotomy between the mathematical and the mechanical, and fostered increasing research on mathematical instruments.[1] This instrumental research, and the use of other mathematical aids, represents a definite break with traditional methods and standards of solution, with the result that computation legitimately took the place of proof for most applied mathematicians.[2] It can be said in summary that the members of this movement adopted an approach that gave predominance to the operational and utilitarian aspects of mathematics.

Of the next two categories, the mystics, and the artists and artisans, less need be said within the context of Petty's mathematical development. The mystics shared with the applied mathematicians a sense of the practical utility of mathematics; but wedded to this was a profound philosophical attitude in which Hermeticism, neo-Pythagoreanism, neo-Platonism, magical astrology, cabalism and the Lullian search for the symbolic key to universal knowledge all played a part.[3] Of these John Dee was probably the most influential sixteenth century English figure, but it was a tradition which in itself held only a subordinate appeal for Petty. The artists and artisans for their part were involved with mathematics through their efforts in the fields of perspective and projective geometry, which were themselves a product of the optician's practical concern for the design of lenses, with its theoretical investigation of the principles of vision, and the artists' attempts to reproduce

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1. See: A.J.Turner: 'Mathematical Instruments and the Education of Gentlemen' Ann.Sci., 30 (1973), 51-88.
2. A brief analysis of contemporary English views on this subject is given in Turner, 'Mathematical Instruments ...' op.cit., 58-61, where the heated debate between Delamain and Oughtred is examined.
3. See A.G.Debus: 'Mathematics and Nature in the Chemical Texts of the Renaissance', Ambix, 15 (1968), 1-28. Dee played a significant role in the growing tradition of applied mathematics in England. cf. C.Hill: Intellectual Origins, op.cit., pp.17-21.

nature as realistically as possible.[1] Quite clearly this tradition made a significant, but short-lived contribution to Petty's general mathematical education. The last category, one of the most important for the general development of mathematics in the seventeenth century and for Petty as an individual, was that of the analysts. In this new and evolving tradition the original innovators were predominantly French, and almost all of them worked outside the official university environment. They shared with the classical geometers a profound admiration for Greek mathematics and a desire to reconstruct such sources from existing fragments. At the same time the analysts fully absorbed the dedication of the cossists to algebra, regarding it as potentially the greatest problem-solving technique available. They also accepted the views of the applied mathematicians that the Greek models were only points for further departure, whose rules should not be allowed to constrict future progress. Finally, the analysts shared the aim of the mystics in that they wished to create a symbolic mode of reasoning which would unify and illuminate the whole corpus of mathematics.

The independent existence of these six traditions during the seventeenth century, and the continued fragmentation of the mathematical world, meant that no single exemplary model or attitude gained control over its competitors. Without a universally accepted heuristic path, the mathematical education of each individual, coupled with his particular personality and intellectual experience, led him to formulate a view of mathematics which was necessarily unique. Just as this is true of Pierre de Fermat or John Wallis,[2] two of the greatest mathematicians of the period,

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1. Figures like Alberti, Durer and Desargues were members of this group. Cf. R.Taton, L'Oeuvre mathematique de G.Desargues (Paris, 1951).
2. This point is forcefully argued by Mahoney in Fermat, op.cit, pp.20-25. The same conclusion can be drawn about the mathematical interests of Wallis, although he reflected a broader, Baconian attitude to natural philosophy. For Wallis's extensive interests see the bibliography of his contributions to the Philosophical Transactions, in Scott, Wallis, pp.230-233, 'Appendix III'.

so it is also true of William Petty, who is rightly remembered not for research into abstract mathematical techniques, but for his application of these methods in simplified form to social and economic phenomena.

A number of the various elements and personalities responsible for Petty's mathematical development have already been referred to. It will be remembered that by the time he was fifteen Petty was forced to give up seafaring:

> '... as not being able to bear the envy of our Crew against Mee for being able to say my Compasse, Shifting Tides, keep reckoning with my plain Scale, and for being better read in The Seaman's Kalender, the safeguard of Saylers etc. than Seamen of our Ship ...' 1

Thus at an early age he was proficient in the basic arithmetical and geometrical procedures of practical navigation, which was an important and rapidly developing area of applied mathematics. Undoubtedly he was also aware through this particular experience of the growing need for accurate mathematical techniques which could solve practical problems on which lives and trade intimately depended. The next stage of his mathematical training occurred during his stay in the Jesuit colleges at Caen and La Flache, where he received instruction in certain mathematical 'trades' and was probably introduced to the tradition of classical geometry

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1. Lansdowne, P.S.C., pp.216-217. The first book is, J.Tapp: The Seaman's Kalendar, or an Ephemerides of the Sun, Moon and most notable fixed Stars, (London, 1601). This contained day-to-day tables of the sun's right ascension and declination, with the day and hour of new moons; these were preceded by an explanation of how to 'shift the tides' (based on a $29\frac{1}{2}$ day lunar cycle), which was the first thing a boy learned when he went to sea. Tapp's work also led the student to consult Recorde's or Blundeville's elementary arithmetical text books. The Seaman's Kalendar appeared in revised editions, which contained such innovations as tables of sines and trigonometric techniques, until in 1631 its publication was taken over by Henry Bond. For Tapp cf. Taylor: Mathematical Practitioners, pp.56-57, 193, 337, and for Bond, ibid., 201-208, 352. The second work quoted by Petty is R.Norman (trans) The Safeguard of Saylers, or Great Rutter, (London, 1584). This gave information on coastal soundings, courses and channels, covering the shorelines of England, France, Spain, Ireland, Flanders and the Sound of Denmark. Re-edited by Tapp in 1612, it was a standard work until 1700, cf. Taylor, op.cit., pp.173, 326.

through study of the works of Clavius or Euclid.[1] It also seems likely that between his departure from France in 1638 or 1639 and his arrival in Utrecht in late 1643, Petty was fortunate enough to establish a link with William Oughtred, one of England's foremost exponents of applied mathematics, who was also an entirely selfless and dedicated tutor in the mathematical arts.[2] Even a short association between Petty and the greatest seventeenth century teacher of mathematics in England would have been of direct benefit to the young man, just as it was for contemporaries such as Wallis, Ward, Scarborough and Wood. From Oughtred Petty may have gained his first solid knowledge of algebra,[3] and more particularly of the algebraic techniques of Francois Viete, who founded the French School of analysts. In addition, knowledge of Oughtred's other work in music, conics, optics and dialling would have reinforced Petty's early mathematical training and embedded it even more firmly in the rich Anglo-Dutch tradition of applied mathematics.[4] Oughtred may even have given Petty one further gift by prompting him to approach John Pell when he journeyed to Amsterdam.

On his arrival in Holland Petty therefore possessed enough skill, knowledge and sensitivity to take full advantage of the enormously fertile

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1. Petty's mathematical education at Caen probably equalled Barrow's at Oxford, cf. Ward, Lives of the Professors of Gresham, op.cit., p.158. The nature of mathematical training in European universities is unclear. For France, see F. de Dainville 'L'Enseignement des mathematiques dans les Colleges Jesuites de France due XVI^e au XVIII^e siecle' Rev.Hist.Sci., 7, (1954), 6-21, and 109-123.
2. See F.Cajori William Oughtred, a Great Seventeenth Century Teacher of Mathematics (Chicago, London, 1916).
3. Oughtred's Clavis Mathematicae (London, 1631) was composed as an instructional text in Algebra.
4. For evidence of this prolific output, and relations between Dutch and English mathematicians in the important area of commercial arithmetic, see H.W.Thomson and B.S.Yamey: Foreign Books on Bookkeeping and Accounts, 1494 to 1750. A Bibliography, (London, 1968), pp.15-18; and idem, Accounting in England and Scotland : 1543-1800. (London, 1963), pp.169-170, for Dafforne's Merchants Mirrour, (London, 1640).

world of Dutch mathematics.[1] Quickly enrolling at Leyden university (which boasted an engineering school founded on German methods and pioneered by Simon Stevin at the beginning of the century)[2] Petty soon established firm contact with Pell. Association with this young professor proved to be crucial for the further development of Petty's mathematics. In 1644, John Pell was one of England's leading mathematicians[3] and was directly linked with the most innovative mathematical figures in France, Holland and his own country. As his correspondence with Sir Charles Cavendish between 1641 and 1647 shows, Pell knew almost immediately of the most recent achievements of mathematicians such as Fermat, Roberval, Descartes, Mersenne, Warner, Mydorge, Hobbes, Carcavi and St. Vincent.[4]

One striking feature of Pell's own mathematical work was his deep involvement with the historical background and current progress of algebra or the 'analytical art'. This involvement covered both the classical origins of algebra and its more recent progenitors in France and England. Thus, one of the projects on which he was engaged throughout the 1640s was the reconstruction and exegesis of the analytic techniques of Diophantus.[5] Another of his prime interests was organisation and

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1. Aubrey noted of Petty that: 'at 18 he was (I have heard him say) a better Mathematician than he is now: but when occasion is, he knows how to recurre to more mathem. knowledge ...', Keynes, Bibliography, p.86.
2. Cf. C.Barton: 'Simon Stevin', op.cit., 244. German public lectures on mechanics, delivered in the vernacular, were renowned. For contemporary reference see, J.Wilkins: Mathematicall Magick. (London, 1648), 'To the Reader'.
3. This pre-eminence was recognised in his election to the professorial Chair at Amsterdam in 1643, and then at Breda in 1646; cf. letter Pell to Cavendish (c.1651), Protectorate of Oliver Cromwell, ed., Vaughan op.cit., ii, 381-2.
4. For this information flow cf. ibid, 345-382; H.Hervey 'Hobbes and Descartes' op.cit., J.Jacquot 'Sir Charles Cavendish' op.cit., 181-184.
5. Pell taught the analytics of Diophantus at Amsterdam and Breda. Cf. Vaughan, op.cit., ii, 364, 373 and Hervey, op.cit., 80. For the views of Descartes, Fermat etc., cf. Mahoney, op.cit., pp.30-33.

sponsorship for the publication of the collected works of Viete.[1] It is hard to overestimate Viete's importance for the rapid evolution of analytical algebra in the seventeenth century, since he undoubtedly exercised a most profound influence on subsequent innovators in this field, of whom Fermat was perhaps the most brilliant and certainly the most indebted to his pioneering efforts.[2] Even Descartes, who disclaimed knowledge of any algebraic source other than Oughtred's Clavis, was through that work alone directly influenced by Viete,[3] and his bitter controversy with Fermat over their rival methods followed lines which were inescapably directed by the previous research of the great early French algebraist.[4] For his part Pell regarded Viete's work with a critical admiration which stemmed from a full understanding of his contribution to, and the subsequent development of, this radically new tradition:

> 'For, if I be not much mistaken in Vieta's writings, there are many dark and unusual expressions fit to be illustrated; and a considerable number of truths merely affirmed by him, not all, or not sufficiently demonstrated; and, perhaps, a few things (but not so many as some suppose) affirmed for truths, which are not so, at least in so large and general terms as we find them there set down - these ought to be limited'. 5

Thus Pell's motivation led him far beyond the static role of admirer, and throughout the decade he attempted to make his own contribution to progress in this field:

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1. Cf. Pell to Cavendish, Vaughan, op.cit., ii, 347-354; also 370, 371. Van Schooten the younger eventually published Viete's collected works at Leyden in 1646, confirming an interest in Vietan algebra dating from 1640. Cf. Smith, op.cit., i, 425; Scott, History, p.243; idem, Wallis, p.211.
2. Mahoney, op.cit., chapter 2, 'Viete's Analytic Program'.
3. Hervey, op.cit., 78, Pell to Cavendish March 2/12, 1646, quotes Descartes. 'He says he had no other instructor for Algebra than ye reading of Clavy Algebra above 30 yeares agoe'.
4. For Descartes and analytic algebra see: C.B.Boyer; 'Descartes and the Geometrization of Algebra', American Mathematical Monthly, 66 (1959), 390-393; C.B.Boyer: 'Fermat and Descartes' Scripta Mathematica, 18 (1952), 189-217; M.S.Mahoney, op.cit., p.32.
5. Vaughan, op.cit., ii, 350; letter dated 12 October, 1642, recipient unknown.

> '... analysis is not the only way to find truths; nor algebra the only field wherein to exercise analysis; nor is Vieta's way the only algebra; nor hath Vieta perfectly taught all that belongs to his way, as, perhaps, I should have shewn clearly ere this time, had I not been hindered by the continuance of innumerable diversions, which I need not mention to you that have known me above these thirteen years. Howsoever, there lies by me no small apparatus to this purpose being the work of all the spare minutes of many years.' 1

Pell was rightly aware of the enormous potential that analytical algebra possessed for application in many new directions, and he was deeply immersed in the development of these increasingly complex techniques, which themselves constituted the watershed of mathematics in the seventeenth century.

Unquestionably, it was through Pell that William Petty gained full initation into these new mathematical skills. As he wrote to Pell after his transfer to Paris in 1645:

> 'I could wish, with Sir Charles, that we could see your way of Analyticks abroad; or, if a Systeme of ye whole Art were too much to hope for, for my owne part I could wish wee had your "Deophantus", which was ready for ye press before my departure from you. Those rules of Algebra (though few) which you gave me, and exercise, have made mee able to do many pretty questions. I entend to reade no Author of that Subject, untill I may be so happie to reade something of yours'. 2

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1. Ibid, 353. This work on algebra was never published in its entirety. The letter shows he was aware of other recent sources. One earlier writer who deeply influenced Pell was Harriot. Thus, to Cavendish, October 14/24, 1651, Pell says: 'My papers ... I have now under hand, tending (I thinke) to the same ends that those speculations of Mr. Harriot's doe' cf. H.Hervey, op.cit., 90. For Harriot see: C.Hill: Intellectual Origins, pp.139-144, infra; Taylor, Mathematical Practitioners, pp.182-183; Scott: Wallis, op.cit., pp.195-197, and p.208: 'Pell was a great admirer of Harriot, and he remarked that had Harriot published all that he knew in algebra he would have left little of the chief mysteries of that art unhandled.' D.T.Whiteside, 'In Search of Thomas Harriot', Hist.Sci., 13 (1975) 61-70.
2. Brit. Mus., Sloane MSS. 4279 f.183.

Petty's devotion to Pell's methods reflect the deep formative influence that the more experienced mathematician provided during their two years of association in Holland. Simply on a personal and circumstantial level Pell introduced Petty to the world of continental mathematics. As their previously-quoted correspondence reveals, Pell was instrumental in gaining access for his pupil to senior figures among the ranks of Dutch mathematicians such as Golius and Van Schooten the elder.[1] However frequent their meetings it is highly likely that Pell supplied Petty with regular information about the exploits of more exciting and exacting mathematicians such as Descartes or Fermat. The fortuitous concentration of these influences led Petty to make what was almost a quantum leap in understanding, when he grasped the basic nature and potential of algebraic analysis. Whether he was then able to follow the increasingly complex stages of contemporary debate over new developments in this field is not important.[2] The really significant fact is that Petty completely absorbed the essential elements of algebraic technique. He experienced a profound realisation that the basic method of algebra links one or more unknown quantities with known quantities in an equation, and then operates on that equation as if all the quantities were equally known. In other words he saw clearly that algebra aims to express the unknown quantities in terms of combinatory products of the known and thereby to make the unknown quantities known. Furthermore, following the lead of Vietan analysis, he was aware, at least on a basic level, that there must be a clear understanding of the abstract structure underlying the theory of equations and their practical application to the solution of problems.

In his later years Petty gave a concise exposition of this under-

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1. See above, Chapter 1, pp.29-36.
2. There is no evidence in Petty's printed works or manuscrips to suggest he was responsible for theoretical research into mathematical techniques, and although he was a competent mathematician it is unlikely that he understood all the mathematical controversies generated during the 1640s in France.

standing, which was stated in the clearest possible terms. Writing a letter to Sir Robert Southwell and including a paper designed as basic instruction in algebraic method for his friend's son Edward, Petty distilled in this text his view both of the method's fundamental characteristics and of its historical development. As such it deserves to be quoted extensively:

[3 November, 1687]

'Sir,

You have asked me once or twice what Algebra was. I answered that it was a kind of Logick, and a more refined way of reason upon common and easy principles, by adding and substracting not onely numbers but the several species of things. Also I might have added that the art of adding, substracting, multiplying and dividing of species, with their rootes, powers and proportions, is called the Algorithme of Algebra; and is done by noting the severall species of things by letters or other characters, and by signifying the severall operations of your Algorithme by characters; all which characters or marks are called Symbolls.

[Petty then gives a table of these basic algebraic symbols, here omitted]

I next propound an easy question to bee answered by Algebra, or a Chayne of argument drawne out of these two common notions onely, vizt:

(1) Things that are equall to a third thing are equall to one an other.

(2) If equalls be added to equalls the totall will be equall, and if substracted the remainders will be equall.

[There follows a simple problem which is omitted.]

Memorandum: That in the foregoing question the Algorithme was simple and the acciomes very few and plain, but yet many intricate questions may be solved even by so much. But where the algorithme is more operose, and where the stock is all the truth in nature that can be expressed in number, weight, and measure, it is not to be imagined what a number and variety of light truths may bee deduced by Algebra.

Memorandum: That as much Algorithme and acciom may be learnèd and mastered in three months, as will produce the solution of a vast number of importante questions; but the dextrous use and application of the

same, soe as to bee free from oversight and Paral-egisme, may well require three yeares study and practice.

This I have written that you may see whether you will ingage your son upon this faculty and way lr' Logic, as also at what yeare you will begin to put him upon it.

The contents of this Paper are: (1, To tell what Algebra is. (2) What Algorithme is. (3) What symbolls are. (4) To state a question in symbolls. (5) The stock of axiomes and truths. (6) To forme the chayne and series of Argument. (7) To keep an account of each equation in the Margent.

So as in Algebra: (1) The Algorithe is the Tooles. (2) The stock of axiomes as the Materialls. (3) The practice and a good head as the workemanship. (4) The finding out abstruse truths is the work, and out of a few truths to draw out infinite true conc[lusions] and to preserve the method of numbering unconfounded is the exc[ell]ency.

Archimedes had Algebra 1900 yeares ago but concealed it. Diophantus had it in great perfection 1400 yeares since. Vieta, DesCartes, Roberval, Harriot, Pell, Outread, van Schoten and Dr. Wallis, have done much in this last age.

It came out of Arabia by the Moores into Spaine and from thence hither, and W[illiam] P[etty] hath applyed it to other then purely mathematicall matters, viz: to policy by the name of Politicall Arithmitick, by reducing many termes of matter to termes of number, weight, and measure, in order to be handled Mathematically. The second, 5th, and 10th Bookes of Euclid, doe make a great parte of the stock above mentioned'. 1

The paper summarises almost all the elements that made up Petty's experience of this mathematical tradition. Like Descartes and Fermat he recognises the early, implicit origins of algebra which were subsumed in the work of Diophantus, Archimedes and Euclid. From Pell's introduction and his later experiences in Paris, Petty lists the leading figures of the continental tradition, correctly including within their general corpus Oughtred, Van Schooten, Harriot and Wallis. Finally, he outlines his own aims and achievements, originally in the application of these techniques to 'other then purely mathematicall matters', and then in

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1. B.H. MSS. 7, 89. Copies at B.H. MSS. 37, Box H 'Royal Society', Folder 4, iii, and B.H. MSS. 11, 39. Accurate printed versions in Lansdowne, Petty Papers, ii, 10-15 and Lansdowne, P.S.C., pp. 318-322. The word 'algorithme' means the method of computing.

terms of the collection and reduction of data to a form suitable for treatment by such methods. At this point it is instructive to compare Petty's high regard for algebra as an ideal problem-solving technique, with Hobbes's original suspicion and contempt. This was due to the great philosopher's early experience of Euclidean geometry, and his belief in its certitude and clarity. Thus, he later 'lamented [to Sir William] that he had not taken the art of algebra more into his Studies'.[1] This illustrates the wide divergence between Petty's view of mathematics and natural philosophy and that of Hobbes, since the former was more concerned with the functional aspect of his work, while the older man searched for certainty based on systematic, self-evident logic.

Discussion of these differences leads naturally to consideration of Petty's broader attitude to mathematics. From his youth, as befitted a Baconian with sophisticated mathematical skills, Petty was interested in such techniques rather as practical tools than as ends in themselves. During his intellectual maturation between 1646 and 1649, Petty expressed strong views over the essential role of mathematics in education:

> 'That the Elements of Arithmetick and Geometry be by all Studied, being not only of great and frequent use in all humane Affaires but also sure guides and helps to Reason, and especiall Remedies for a volatile mind.' 2

In this Baconian view of mathematics Petty was far from unique, yet his advocacy of its utility and its disciplinary value sprang from a deeper personal experience and understanding than that of many other educational

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1. Cf. Lansdowne, P.S.C., p.322. For this aspect of Hobbes' thought cf. S.I.Mintz: The Hunting of Leviathan, (Cambridge, reprint 1969) pp. 6-9. For Hobbes's failure to keep up with mathematical progress and Wallis's justifiable criticisms cf. Skinner, 'Hobbes and the Early Royal Society' op.cit., 220-222.
2. W.Petty: Advice, p.5.

reformers.[1] Yet, as one might expect, Petty's support for mathematics transcended its heuristic function, and in the Advice he asserted the need for a development of new, syncretic mathematical disciplines, founded on material collected from previously non-mathematised fields. For example, when describing the value of a History of Trades he says that the work 'will be a help ...'

> 'To Arithmeticians and Geometricians, supplying them with Matter whereupon to exercise those most excellent Sciences, which some having with much paines once learned, do for want hereof forget againe, or unprofitably apply about resolving needlesse Questions, and making of new difficulties. The number of mixt Mathematicall Arts would hereby be encreased.
>
> For wee see that Opticks are made up of pure Mathematicks, the Anatomy of the eye, and some Physicall Principles concerning the Nature of light and Vision, with some Experiments of convexe and concave glasses, Astronomy is constituted againe of them, and some Cælestiall Phœnomena. Enginry againe of them, and some Propositions de Cochlea et Vette. And so certainly as the number of Axioms concerning severall subjects doth encrease by this work, so the Number of (their Applications to pure Mathematicks, id est,) New Mathematicall Arts, will encrease also.' [2]

It was exactly these 'mixt Mathematical Arts' which provided the common characteristic of Petty's exemplification of Baconian science, particularly in the remarkable success of the Down Survey, and the later corollorary development of political arithmetic. Equally, it is as an example

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1. Bacon made a similar statement in The Advancement of Learning: ' ... men do not sufficiently understand the excellent use of the Pure Mathematics, in that they do remedy and cure many defects in the wit and faculties intellectual. For if the wit be too dull they sharpen it; if too wandering, they fix it; if too inherent in the sense, they abstract it'. Cf. Bacon, Works, p.97. Petty was a far better mathematician than Bacon, or some later Baconians, like John Webster, whose Academiarum Examen (London, 1653), pp.40-52, contained an inept chapter eulogising mathematical sciences.
2. Petty, Advice, p.25. Petty's statement parallels Bacon's in De Augmentis Scientiarum: 'In mixed Mathematicks I do not find any entire parts now deficient, but I predict that hereafter there will be more kinds of them, if men be not idle". Cf. Bacon, Works, pp.475-477. Where Petty differed was his support for mathematics not as 'appendices and auxiliaries' to 'Physics and Metaphysics and Mechanics and Magic', ibid, p.476, but as a method essential to the progress of natural philosophy. For Spedding on Bacon's lack of sensitivity to earlier developments cf. ibid. pp. 476-477.

of Petty's belief in the didactic, practical and philosophical benefits of such 'mixt Mathematical Arts' that the method and subject matter of the Discourse must be viewed.

(e) The Use of Duplicate Proportion in Sundry Important Particulars

Petty's first example contains, naturally enough, the clearest statement of his method:

> 'The First Instance Wherein Duplicate, and Subduplicate Ratio or proportion is considerable, is in the Velocities of two equal and like Ships; which Velocities, I say, are the Square Roots of the Powers which either drive or draw them; as for example, Such two Ships having Sails near double to each other, as 49 to 25, the Velocity will be as 5, the Square Root of 25, unto 7 the like Root of 49 ...' 1

In other words, the sail power of a ship is in duplicate proportion to, or is the square of the velocity of, the Ship, and the velocity or speed of the Ship is in subduplicate proportion to, or is the square root of, the power that drives it.

Proportionate comparison was a common method in contemporary mathematicks and occupies, for example, a central position in Oughtred's Clavis Mathematica.[2] However, if the language and concepts were common mathematical currency, the application of the comparative method to problems outside geometry, such as structural mechanics, was not. During the seventeenth century the leap forward in statics came with Galileo's brilliant, innovative work Discorsi e Dimostrazioni[3] (1638). In this book Galileo applied geometrical techniques of comparative analysis to

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1. Petty: Discourse, pp.21-22.
2. See: Mr. William Oughtred's Key of the Mathematics, (London, 1694) Chapter 6, pp.24-33, 'Of Proportion'.
3. Galileo Galilei: Discorsi e Dimostrazioni Matematiche, Intorno a nuove Scienze Attenti alla Mecanica et i Movimenta Locali ... (Leyden, 1638). For present purposes the translation by H. Crew, A. de Salvio: Dialogues Concerning Two New Sciences : Galileo Galilei,(Dover Reprint, 1954) has been used.

subjects ranging from the parabolic flight of projectiles to the common relationship between sonic vibration and pendular frequency. The great natural philosopher's interests coincided directly with those of Mersenne, who had already arrived at similar but unpublished conclusions in closely related fields.[1] Therefore as well as translating at least two of Galileo's treatises into French,[2] Mersenne and his circle of dedicated colleagues continued to experiment and test many of the hypotheses posited by Galileo in the various 'thought experiments' with which his works abound.[3]

It was into this ferment of activity that Petty moved when he arrived in Paris during 1645. Naturally, the common involvement with Galilean physics, dynamics and optics was of the greatest interest to the young Englishman and he absorbed them all with an ease fostered by his already excellent mathematical and scientific training. However, there is no reason to believe that he materially furthered the production of a single major discovery in these fields at this or any other time. What is far more significant is that this experience reinforced his growing belief in the power and universality of mathematics. As the Discourse shows, this opinion remained with him for the rest of his life, and he thus applied the comparative technique of duplicate proportion to a spectrum of subjects even broader than those treated by Galileo in the Discorsi.

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1. These parallel discoveries are particularly clear in musical theory. See: A.C.Crombie: 'Mathematics, Music and Medical Science' Organon, 6 (1969), 21-36, and especially pp.27-8. See also S.Drake, 'Renaissance Music and Experimental Science' J.Hist.Ideas, 31 (1970), 483-500.
2. For these works cf. bibliography in R.Lenoble: Mersenne ou La Naissance du Mecanisme, (Paris, 1943), pp.xii-xxxi, especially number 14: Les Mechaniques de Galilee ... (Paris, 1634), pp.xx-xxi, Mersenne produced numerous works on optics, mechanics, harmonics etc., and was a powerful advocate of the universal applicability of mathematics coupled with experiment.
3. See L.Hine: 'Mersenne and Copernicanism' Isis, 64 (1973), 18-32; J.T. Clark: 'Pierre Gassendi and the Physics of Galileo' Isis, 54 (1963), 352-70; A.G.Debus: 'Pierre Gassendi and his "Scientific Expedition" of 1640', Arch.Int.d'hist.Sci., 16 (1963), 129-142; and extended analysis in R.Lenoble, op.cit.

Therefore, he included within the scope of analysis the question of the range or differing intensities of light, sound and smell, and he likewise covered musical harmonies and progressions, the frequency of pendular vibration and the explosive force of gunpowder.[1]

In his treatment of these subjects Petty was harking back to his experience in Paris, and was often repeating or extrapolating from the conclusions of Mersenne, Gassendi, Roberval and Mydorge.[2] As a result his analysis of the effects of different weights and tensions on musical strings was clearly derivative, as was the following re-statement of a classic law:

> 'The Tenth Instance : In the Time of the Vibration of Pendules : The times in which the Returns of a Vibrating Pendulum are made, are the Roots of the Distances between the Center of the Pendulum, and the Center upon which it moves'. 3

In repeating these observations, without detailed experimental or mathematical evidence, he was attempting to illustrate the possibility that a limited number of basic mathematical laws might exist which could explain the multiplicity of apparently disparate natural phenomena, without claiming that the particular law he had chosen was necessarily original, correct or accurately applied.[4]

Nevertheless, as a Baconian, Petty intended his treatise to have a

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1. Petty, Discourse, Instances: 9, 7, 8, 12, 10 and 6. For locations see Appendix III, iii. Petty's simplified theory of the volume and range of sounds was developed from knowledge gained in Paris and explains how he fulfilled the duties of Professor of Music at Gresham College in the early 1650s. Cf. Petty, Discourse, pp.70-73.
2. For Petty's continuing interest in these subjects, cf. Lansdowne, Petty Papers, ii, 207-210, 'No.144. Of Motion and Mechanics, 1686'.
3. Ibid, pp.80-82.
4. When delivered as a lecture, Petty reminded his audience that his ideas were far from novel: 'Wherefore I have, together with my old, Dull Notions and apply-cations above mentioned, presented ... a New Theory [of Elasticity].' In the published version, to deny the Society's enemies' ammunition, this was changed to, 'I have, together with My Instances and Applications ...' Cf. ms. version of the Discourse: B.M. MSS. 40, Box K, Folder 9, p.3. and Petty, Discourse, p.3, lines 7 and 8.

more immediate and positive effect than the imprecise re-affirmation of a Neo-Platonic view of nature[1] founded on a well-known continental research which was over thirty years old. Following Boyle's recent advocacy of the utility of mathematics and more especially of duplicate proportion itself,[2] Petty was determined to show that it could be applied to some basic technological problems. Naturally he chose areas of technology which were currently in demand. Therefore one major reason for the work's dedication to Brouncker was:

> 'Lastly, For that near half the whole Discourse relates to Shipping, Artillery, Fortresses, Seabanks, etc. which all concern his Majesties Service, and part whereof are happily entrusted by him to your Lordship's Care; I thought I might express My affection to those his Majesties Concernments even by offering this my Mite unto them.' 3

In fact, as the itemised table demonstrates, over sixty per cent of the tract is taken up with the analysis of subjects relating to trade, industry or technology.[4]

The part of the Discorsi most relevant to Petty's individual interests, and the one which informed and stimulated him most, was Day 2 of the Dialogues, where Galileo dealt with the problem of the comparative strength of wooden beams.[5] There can be no doubt that Petty knew

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1. The only other point where Petty adopts a similar view is in his 'Scale of Creatures'. Cf. Lansdowne, P.S.C., pp.42-48 and Lansdowne, Petty Papers, ii, 21-34. Petty's 'Philosophical' musings were not central to the overall bias of his thought, and these Neo-Platonic tendencies were tentative and peripheral.
2. Robert Boyle, Usefulnesse of Experimental Naturall Philosophy, ... (Oxford, 1671) Essay 2 'Of the Usefulness of Mathematicks to Natural Philosophie' pp.12-18. Boyle also strongly advocates the utility of 'Mixt Mathematicks'. ibid, pp.19-20.
3. Petty, Discourse, Sig.a3r+v.
4. See Appendix III, iii, 'Table of contents'.
5. Crew, da Salvio, Dialogues, pp.104-152. For the historical context of Galileo's work see: A.Pacey, The Maze of Ingenuity, op.cit., pp.112-114, infra; E.Williams. 'Some Observations of Leonardo, Galileo, Mariotte and others relative to size effect', Ann.Sci., 13 (1957) 23-29.

Galileo's treatise, for in an unpublished essay on shipbuilding and hydrodynamics, written prior to 1674, he stated that among others:

> 'The Means and helps which he had to carry on this Work were: ...
> B. The experiments and theorems found in several books of Mechanics, Hydrostatics etc., as in the books of Galileo etc., applicable, though not applied to this subject ...' 1

The importance of Galileo's demonstration for all areas of structural engineering was great, both for calculating the parameters of cost, and in the reduction of load-bearing capacity resulting from increases in scale. Yet in England neither Galileo's work, nor its implications, were known outside the ranks of a few leading natural philosophers,[2] and even for them, knowledge of the behaviour of materials under stress was in its infancy. Consequently, when delivering the Discourse as a lecture, Petty assumed that there was no need to acknowledge directly the particular source of his method, while at the same time he stressed the importance, not of the idea's originality, but of its practical application. Since awareness of Galileo's book seems to have been incomplete (even amongst Fellows)[3] and since Thomas Salusbury's translation was either unobtainable or extremely rare,[4] it is likely that Petty intended to spread knowledge of this work among his immediate colleagues. An additional aim was to simplify Galileo's theories and produce a formula which could be applied to widely differing technical problems, in the hope that under this simplified guise these theories would reach and influence

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1. This essay was finally published in 1931 by Lansdowne, The Double Bottom, op.cit., pp.6-13. Cf. p.7. for this quotation.
2. Thus, 10 September, 1662, the Royal Society asked Croune to expedite translation and publication of Discorsi. Cf. Birch, History, i, 109.
3. For example see Hooke's first reference to it, 5 February, 1673, in Diary, ed., Robinson and Adams, p.26.
4. For T.Salusbury Mathematical Collections and Translations (London, 1661-1665) see introduction to reprint (London, Los Angeles, 1967) ed. S.Drake. Wood and Petty were consulted by Salusbury about the book prior to its publication. Cf. Taylor, Mathematical Practitioners, p.370; Barnard 'Symner and ... New Learning' op.cit., 136-137.

the people to whom they were most valuable - those working in basic industrial and mechanical processes. This application of arcane mathematical research to practical problems also fulfilled his earlier dictum on the educational and utilitarian value of 'mixt Mathematical Arts'. Equally, it belonged to a tradition of instructional literature which stretched back through John Wilkins' Mathematicall Magick[1] to Ramelli and Zoncha, though in size, scope and organisation it was didactically less proficient. While not a serious fault in an essay which was never intended to be encyclopaedic,[2] this lack of system becomes noticeable when compared with the ordered framework of Thomas Venn's Military and Maritime Discipline,[3] which in parallel fashion aimed to inform artillerists of Galileo's work on projectiles.

Nonetheless, Petty's application of duplicate proportion to technology indicated the breadth of his knowledge in several important fields. Thus he used the formula to make a rough analysis of the comparative strength of fires, and the expansive capacity of different liquids - reflecting expertise derived from his early research into distillation and industrial chemistry.[4] Other examples were devoted to the force of pumps, the effects of water-power in mills, air pressure in bellows, and the residual strength of mill-dams and sea-banks.[5] For

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1. [J.W[ilkins]: Mathematicall Magick or The Wonders That may be performed by Mechanicall Geometry, in TWO Books Concerning Mechanicall Powers [and] Mechanicall Motions. Being One of the most easie pleasant, usefull (and yet most neglected) part of Mathematicks. Not before treated of in this language (London, 1648).
2. For Petty's statement of this intended role see his letter to Aubrey, May 1678 in Appendix III, vi, 3.
3. Capt. T.Venn. Military and Maritime Discipline in Three Books ... To which is added the Doctrine of Projects applied to Gunnery by Galileus and Torricellio. And Observations out of Mersennus and other Authors, (London, 1672). This handsomely proportioned text-book gave full instructions, and was a standard source for over a century. The parabolic theory, based on Galileo's work, was more fully described in T.Streete, R.Anderson: The Genuine Use and Effects of the Gunns as well Experimentally as Mathematically demonstrated ... with Tables of Projection. (London, 1674), Cf. A.R.Hall: Ballistics, op.cit. pp.56 and 91.
4. Petty, Discourse, pp.91-96, 'Instance Thirteen'.
5. Ibid, Instances 14, 5, 15, and 17. See Appendix III, iii, for page references.

these Petty utilised his first-hand knowledge gained through gruelling involvement with the iron industry in Kerry. This wide application of the square and square-root relationship to industrial technique confirms that it was Petty's consistent belief that all phenomena, whether technological, natural, social or economic, must be amenable to mathematical analysis. He believed that only through the application of such methods could man's control over his environment be speedily improved, and he therefore returned to themes which had dominated his activity in London during the Commonwealth period:

> '... many men designing Engines of Strength, do make Models of such Machinaments by a Scale (Suppose wherein an inch represents a foot) by which the Model is but 1/1728 part of the Engine intended: And thereupon they conceive, that if the Model be strong enough to bear 1/1728 part of what the great Machinament is intended to bear, that then the said great Machinament will be strong enough. Whereas indeed the Model must bear the full 1/144 of what is intended for the great Machinament; otherwise great mischiefs will appear in the Work. Therefore the Square of the Linear Difference between the Model and Engin, is the measure and way of trying the strength and sufficiency sought for: The ignorance whereof hath [un-] made many a poor Projector'. 1

However, of all the fields covered in the Discourse there are two which were closer to his own interests after the Restoration and which exemplify most clearly his aims and methods.

By 1674 Petty possessed an excellent working knowledge of all aspects of small-scale building and structural engineering. This sprang from his development of property in London and Dublin and the construction of dwellings, furnaces, forts and storage buildings in Kerry. Therefore, when presented with the methods and conclusions contained in Galileo's analysis of the strength of materials, Petty had sufficient mathematical comprehension and practical knowledge to visualise the full importance

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1. Ibid, pp.46-48. Blith's comments on the failure of 'projectors' should be kept in mind here.

of the work. In the clearest fashion he grasped the essentials of Galileo's dictum which (stated in modern terminology) becomes: the strength of a beam is proportional to its breadth, and to the square of its depth, and inversely proportional to its length. In addition to his theoretical knowledge of the problem Petty had also started to test the strength of various types and thicknesses of timber under experimental conditions. In conjunction with Hooke he carried out a series of these experiments at the Royal Society in 1663 and 1664, which was later reported and publicised by Evelyn in the second and third editions of Sylva.[1]

Although eight years had passed since the general destruction of London, a massive amount of rebuilding still awaited completion in the city.[2] Naturally, there was intense demand for everything related to the construction industry, from suitable materials to experienced builders. However, an acute shortage developed in both areas, and many owners were forced to attempt personal reconstruction of their property. For these men, and for the country builders who had been attracted into the metropolis, there was little written guidance on how to proceed with the work, apart from the fairly detailed requirements set out in laws which governed the rebuilding programme. One book designed to fill this gap was Primatt's, City and Country Purchaser and Builder,[3] which laid down in straightforward prose simple rules for building methods and dimensions. It was based entirely on traditional empirical knowledge and was referred to by such leading figures as Hooke and Southwell.[4] Apart from this volume there was little else that an experienced builder could

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1. J.Evelyn, Sylva, or a Discourse of Forest Trees ... (2d ed., London, 1670) pp.182-185, describes this experimental work and gives a table of the legal requirements for joists and beams.
2. See T.F.Reddaway, The Rebuilding of London After the Great Fire, (reprinted, London, 1951).
3. S.Primatt, The City and Country Purchaser and Builder, (London, 1668).
4. R.Hooke, Diary, op.cit., p.131, entry for Tuesday, 17 November, 1674: '... Lent Sir Robert Southwell, Primat's City Builder etc ...'

use for guidance, except works on classic architectural style and proportion such as Evelyn's, Parallel of the Antient Architecture[1] or Moxon's, Vignola or the Compleat Architect.[2]

Although Petty was not trying to write a complete textbook for the building trade, he was in the Discourse hoping to provide the common builder with a method which for the first time would help him formulate a working estimate of the strength of the timber he used. Thus, in the second 'instance' of the Discourse[3] Petty employed and simplified Galileo's work to show how the formula was derived from experimental procedures, and how it could be used to maximise the strength of scantlings and beams in a house, while minimising the amount of timber consumed. The latter result was of the greatest concern to contemporary builders, for (as Primatt noted in 1668) 'the price of Fir-timber [has] doubled since the late Fire'.[4] In his concluding remarks to the second instance, after showing how to calculate the strength of timbers in a test example, Petty summarised the benefits of the method, and his attitude to its utilisation:

> 'This saving of stuff is the reaon [for] dividing Plank into Girders, Gise and Board. Where[fore] note, that these Proportions and scantlings are not offered as exact and best for practice, but onely to intimate the method of inquiring into these matters so useful in the world.' 5

This obscure treatise, then, holds a unique position in the literature of building science,[6] and is the earliest published application in England

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1. J.Evelyn, A Parallel of the Antient Architecture with the Modern, (London, 1664).
2. Ja: Barazzio, translated by J.Moxon. Vignola, or the Compleat Architect. (London, 1655). Later editions: 1665, 1673, 1694.
3. Petty, Discourse, pp.41-55.
4. Primatt, op.cit., p.61.
5. Petty, Discourse, p.55.
6. For the history of structural analysis see: S.B.Hamilton, 'The Development of Structural Science in the Seventeenth and Eighteenth Centuries', (Ph.D. Thesis, London University, 1950) especially p.30; A.Wolf, A History of Science, op.cit, ii, Chapter 21, especially p.484; S.B.Hamilton, 'The Place of Sir Christopher Wren in the History of Structural Engineering', Trans.Newcomen Soc., 14, (1933-34), pp.27-42; H.J.Cowan, An Historical Outline of Architectural Science, (London, 1966), Chapters 1 and 2.

of the principles enunciated in the second section of Galileo's Discorsi. While it is true that Petty's work on the strength of materials exhibits none of the brilliant experimentalism to be found in Hooke's De Potentia Restitutiva,[1] it would be unreasonable to judge it on this criterion alone, since Petty's purpose and method were so different from those of Hooke. Instead it is far more appropriate to compare the Discourse with John Wilkins' Mathematicall Magick. Just as Wilkins hoped to bring a simplified version of Archimedean mechanics to a wider public, so Petty tried to perform the same task for Galilean statics. Finally, if Petty's attitudes and suggestions had been systematically pursued by others, specific areas of building technology and science might have taken less time than they did to develop as separate and professional fields of knowledge.[2]

A more reasonable comparison between the experimental techniques of Hooke and Petty can be drawn if the latter's systematic research into a wide range of nautical problems is taken into consideration. Naval matters exercised a profound fascination for Petty in terms of economics, strategy and also through his desire to further the practical improvement of hull shapes using direct experiment and mathematical analysis. In fact there is overwhelming evidence that Petty's understanding of the complexity of naval design and hydrodynamics far outstripped that of most contemporary experts. In the same manner his experimental technique seems to have been more complex in its aims and execution than theirs.

The only published outlet for this research came in certain sections

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1. Robert Hooke, Lectures De Potentia Restitutiva or of Spring, Explaining the Power of Springing Bodies, (London, 1678) in R.T.Gunther, Early Science in Oxford (Oxford, 1931) 331-360. For Hooke's theoretical work see: E.Williams, 'Hooke's Law and the Concept of the Elastic Limit', Ann. Sci., 12 (1956) 74-83; idem, 'Some observations of Leonardo, Galileo, Mariotte and others'. op.cit. 23-29.
2. Thus, development of Petty's work would have promoted reference tables for the strength of various thicknesses of beam, similar to those used in the nineteenth century: see J.Gwilt: An Encyclopaedia of Architecture Historical, Theoretical and Practical, (3rd Ed., London, 1854), pp.421-452, "Mechanical Carpentry".

of Petty's Discourse of Duplicate Proportion.[1] His co-operative work with colleagues was directly alluded to in the second chapter of the book:

> 'I say, that the different velocity of Bodies (of several sharpnesses, and as drawn or driven by different powers of knocks or falling weights) have been by myself and others much experimented in large canales, or troughs of water, fitted with a convenient Apparatus for that purpose, and by no man more, nor more judiciously, than by the Right Honourable the Lord Brouncker, President of this Society.' 2

Petty's wide experimental and practical knowledge of naval matters provided the basic material over which his approximative method of the inverse relationship between square and square root could range. Naturally, only a minute proportion of this material could be used in the Discourse, and even that was drastically reduced to a simplified form that would be comprehensible to craftsman, virtuoso and sailor alike.[3] Petty illustrated through appropriate examples how the resistance of a ship could be calculated according to the shape and depth of its bow, how its sail power could be estimated, and how these two functions could be integrated to provide a rough prediction of its potential speed. With this knowledge the efficiency of the ship could be improved:

> 'By these ways the different Velocities, arising from the different Trim of the same Ship, may be also computed, the best Trim being that which makes least resistance, caeteris paribus.' 4

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1. Petty, Discourse, pp.21-41, 44-46, 55-60, 100-102, 106-108, 109-110 cover naval topics.
2. Ibid, pp.36-37.
3. The work was designed to explain, 'Intricate Notions ... in a way which the meanest Member of adult Mankind is capable of understanding': and show the use of duplicate proportion, 'in some of the most weighty of Humane affairs, which Notion a Child of 12 years old may learn in an hour' cf. ibid, 'Epistle Dedicatory'. Sig.A4r-A5r. It was also expected to educate craftsmen: 'It may well be askt, How we know the same, since that very few Seamen or Shipwrights, either in their writing or discourse seem to understand or own this important Position.' ibid, pp.34-35.
4. Ibid, p.28.

Other related topics where the formula of 'duplicate and subduplicate proportion' was applied were in the calculation of the amount of timber needed for different sizes of ship,[1] in the comparative strengths of hulls (consciously extrapolating Galileo's work on the strength of beams) and in the rough costing of different sizes of ship timber and masts.[2] By comparing and integrating a group of these variables Petty carried out what was the first objective mathematical analysis in which shipping costs were balanced out against factors of carrying capacity and speed:[3]

> 'Now, having said thus much of the Effects of Sharpness and Sails (the two principal causes of velocity in Shipping, and unto which all others may be referred;) I shall add, That the want of these two Advantages are the chief cause, why Short, bluff, undermasted Vessels sail cheaper than others ... I say, this consideration is of great weight in Vessels of burden [i.e. time spent at sea instead of in dock, lower wage costs, differentials in construction costs] especially such as carry gross and cheap bulky Commodities, neither liable to damage or perishing: Of which goods 7 parts of 10 of all Sea-carriage do consist.' 4

Altogether Petty hoped to provide English mariners and shipwrights with a simple, mathematical tool which could give a rough, but sufficiently accurate, method for isolating and quantifying previously complex functions.

Given the above information, what assessment can be made of the attitude to mathematics and natural philosophy which lay behind the Discourse? The most obvious element was Petty's fundamental belief that mathematics, when applied correctly and linked with experiment or the systematic collection of data, provided one of the basic keys for unlocking nature's hidden regularities. Another element was Petty's change of emphasis from research

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1. Cf. Sharp 'Timber, Science, Economic Reform' op.cit., 69-70.
2. Harriot was working on similar problems such as the relationship between the breadth, length, depth of a ship and corresponding mast sizes. Cf. mathematical commonplace book for 1599-1600, Brit.Mus., Additional MSS. 6788 ff. 1-50.
3. Petty's conclusions should be compared with the evolution of specialised Dutch vessels designed for low-cost transport of bulky goods. See V.Barbour, 'Dutch and English Merchant Shipping', op.cit.
4. Petty, Discourse, pp.29-34.

to instruction. Whereas Galileo produced experimental material that linguistically and conceptually went far beyond the grasp of the average craftsman, Petty tried to simplify and distil the core of Galileo's results in a didactic work. In so doing he was forced to reduce his own experimental achievements to the same simplistic level. Nevertheless, the fact that he carried out such a broad range of naval experiments, and the fact that his knowledge of natural philosophy and industrial technique were so widespread enabled him to go beyond the position of merely repeating Galileo's work in a more basic form. Because of this experience he was able to produce further, independent evidence from areas which he felt corroborated and extended the relationship present in the more rigorously definitive work of the great Italian scientist. The lack of exactitude was dictated by the size, scope and approximative character of the Discourse. These equally prevented Petty from making absolute statements about the various mathematical relationships which seemed to link certain phenomena. Instead, he followed Galileo's lead insofar as he showed that key factors could be isolated and analysed,[1] thereby encouraging others to use his simplified methods (where parameters allowed) and stimulating further detailed experimental work in those areas where the precise operation or result of the method was to open to question:

> 'The which are not only gross enough of themselves, but are also as grossly handled in this Exercise to prevent the further imputation of needless Nicity, and to leave room for your own further thoughts upon the same.' 2

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1. W.B.Parsons: Engineers and Engineering in the Renaissance, (M.I.T., reprinted 1968), p.481, maintains that Galileo, by showing how to isolate and analyse stresses in materials to establish their resistance to strain, 'cut a vicious circle of ignorance' which until then hindered the architect and structural 'engineer'. See also S.P.Timoshenko: History of Strength of Materials ... (London, 1953) pp.11-15; E.Straub, A History of Civil Engineering, (London, 1952) especially pp.62-67; J.R.Ravetz, 'Galileo on the Strength of Materials' School Science Review, 43 (1961-2), 52-57.
2. Petty, Discourse, pp.2-3.

(f) The Mechanical Philosophy

In the final pages of the Discourse of Duplicate Proportion Petty gave a unique description of the basic mechanisms which he believed underlay all natural phenomena. At no other point in his writings does such hypothetical and speculative reasoning about the mechanical philosophy appear. As a statement about fundamental physics it was short, cursory and consciously inconclusive.[1] Earlier in the work Petty claimed that, while the rest were old, the ideas in this final 'Appendix of Elasticity' were completely novel:

> 'And forasmuch as We have been also complained of for producing nothing New, I have together with my Instances and Applications, above and hereafter mentioned, presented you as an Appendix, to what is said of springs and other Elactique bodies, with a New Theory (as I think) of Elasticity it self, and that mechanically explicated in order to make a breach on this hard Rock in Philosophy ... ' [2]

Yet, as will be seen, the most that can be said on the originality of these theories is that they represent an idiosyncratic amalgm of ideas current in natural philosophy during the 1640s and 1650s. Once again they are significant, not because of their scope or their novelty, but because they provide unique information about Petty's own views on a central problem in natural philosophy, and help to illuminate the attitudes of other leading figures towards the same subject at the same time.

For Petty the prima materia of the universe was the atom, 'such, whereof perhaps a Million do not make up one visible Corpusculum'.[3] These immutable atoms could vary widely in terms of 'Figure' and 'Magnitude', and through their motions link up to make mutable corpuscles whose size,

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1. Ibid, pp.121-122: '... I hope it will not be amiss to subjoyn a short Appendix of Elasticity it self, whereby to draw forth the better thoughts of other men for countenance or correction'.
2. Ibid, pp.3-4.
3. Ibid, Sig.A5r.

motion and shape determined all secondary qualities.[1] Petty's atoms, however, resembled microcosmic models of macrocosmic planetary systems:

> '6: I suppose in every Atome three such points as we all see and know to be in the Globe of the Earth, and in every Magnet, viz. two Poles in its Superficies, and a Central point within its substance, by which I call its Byas. The Heavens also visibly have their Poles, and must have a Center of Gravity or Magnitude, a some other Central predominant Point.
> 7: I suppose 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 Satellite Jovis about Jupiter, etc.' 2

Thus, like the solar system, this sub-microscopic world cohered through axial motion and orbital regularity derived from reciprocal kinetic attraction. Equally, all atoms possessed magnetic characteristics, in that they manifested distinct motive tendencies: 'Gravity' which pulled them towards the centre of the earth, and 'Verticity' which pulled them 'towards the Earth's Poles, ... just as Magnets joyn to each other by their opposite Poles'. Without their attraction to each other's central point or 'Byass', all atoms would tend to form long chains, like magnets placed end to end. As it was, this mutual attraction between central points forced them to adopt triangular relationships whereby the axes of any two atoms formed two sides of a triangle, and the distance between their central

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1. See R.Kargon, 'William Petty's Mechanical Philosophy' Isis, 56 (1965), 63-66; idem, Atomism in England from Harriot to Newton, (Oxford, 1966) henceforward, Kargon: Atomism. This book is plagued by referential and historical inaccuracies. For example, on Petty's mechanical philosophy, pp.68-70, the title of the Discourse is misquoted (p.69, n.1.), a garbled quotation is given, with the wrong location (p.69, n.7.), and Petty's earlier intellectual pursuits are limited solely to mathematics (p.69). For other examples compare Kargon's treatment of Charleton's intellectual development with that in L.Sharp: 'Walter Charleton's Early Life ...' op.cit., especially 325 and n.47, or his inaccurate statements about Margaret Cavendish, Atomism, p.77, with Sharp: 'Walter Charleton', op.cit., 329-331. Kargon's work is, however, a useful adjunct to primary sources. See also T.F.Mayo 'Epicurus in England (1650-1725)', (Ph.D. thesis, Columbia University, 1934); C.T.Harrison, 'Bacon, Hobbes, Boyle and the Ancient Atomists' Harvard Studies and Notes in Philology and Literature, XV (Harvard, 1933), 191-218.
2. Petty, Discourse, pp.125-127.

points made up the other. All the velocities of the atoms might assume different magnitudes and directions. Ultimately these variations or oscillations in corpuscular motion, when allied with particulate shape, caused the infinite diversity of secondary effects found in natural phenomena.[1]

Towards the end of the Appendix Petty emphasised two elements in this hypothetical explanation of atomic mechanisms. Firstly he stressed that, by postulating a model for the sub-microscopic world which mirrored exactly that of its macrocosmic counterpart, he had provided an explanation which united all natural phenomena within a common system, centred on a few basic principles. As a corollary this system would therefore be amenable to experimental verification and mathematical analysis, since physical experiments with macrocosmic phenomena should by direct analogy have revealed identical developments at particulate level.[2] Secondly, he followed the lead given by Hobbes in arguing that motion was the normal state in nature; when matter appeared to be static it only reflected a situation in which conflicting motions or 'contra-colluctations' of its corpuscles were temporarily balanced. Stasis, therefore, was only a transitory and illusory phenomenon.[3]

Given this rigorously mechanistic system, it is surprising to find that Petty introduced a further, vitalistic element into the general schema. In the penultimate section of the Appendix he offered a theological justification for his mechanical universe, by arguing that atoms were either male or female, and that the attraction of their centres provided the point where generative 'coition' took place. Through this ingenious idea Petty clearly hoped to obviate the criticism that the Biblical account

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1. Ibid, pp.127-129.
2. See conclusion to this Appendix, ibid, pp.132-134.
3. Ibid, p.130. '... I say, seeming [rest], because perhaps there is no rest in Nature'. For this cf. Kargon, Atomism, pp.57-59.

of the Creation failed to mention atoms:

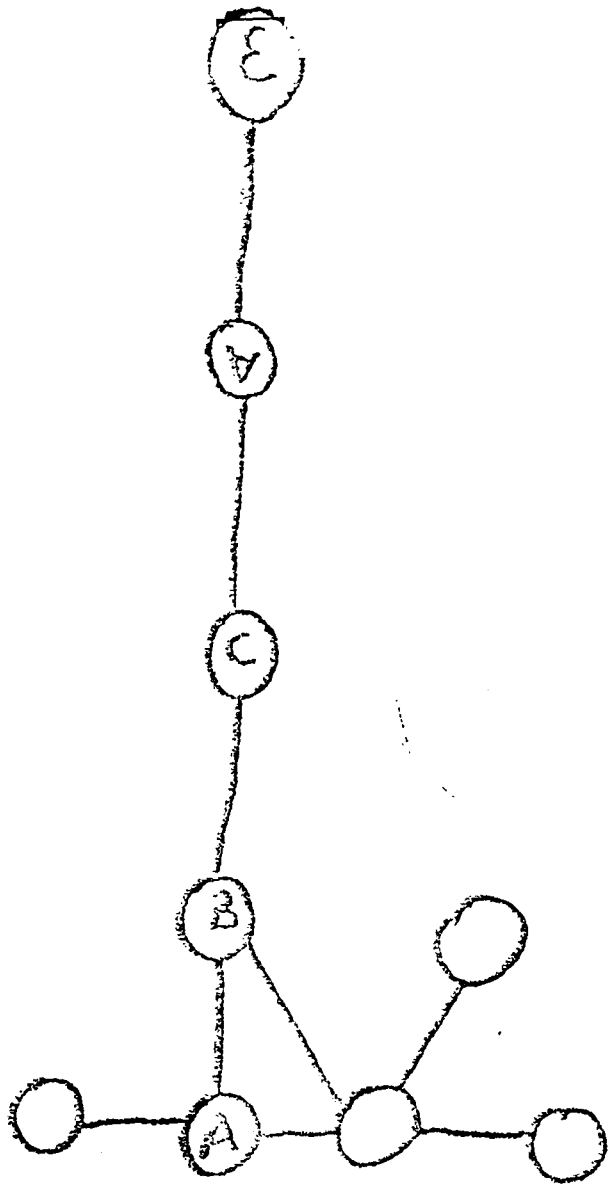
> 'Nor is it absurd to think that the words in Genesis (Male and Female created he them) may begin to take effect, even in the Smallest parts of the first Matter. For although the words were spoken onely of Man; yet we see they certainly refer to other Animals, and to Vegetables in manner aforesaid, and consequently not improbably to all other Principles of Generation.' 1

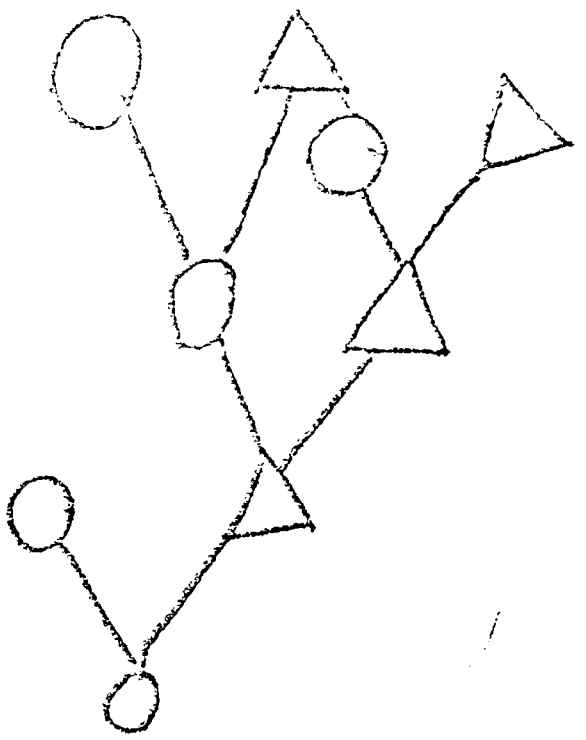
In adopting this argument he took the Mosaic defence of natural philosophy and atomism one stage further. But unlike Charleton, Boyle, Cudworth or Newton,[2] Petty introduced a vitalism which was inconsistent, both with regard to his normative statements within the Discourse, and to his more broadly-defined attitude to natural philosophy. Even within its own terms such an argument must have been anomalous, since if atoms were immutable they could scarcely have undergone a reproductive process which necessarily included changes such as conception, gestation and birth.

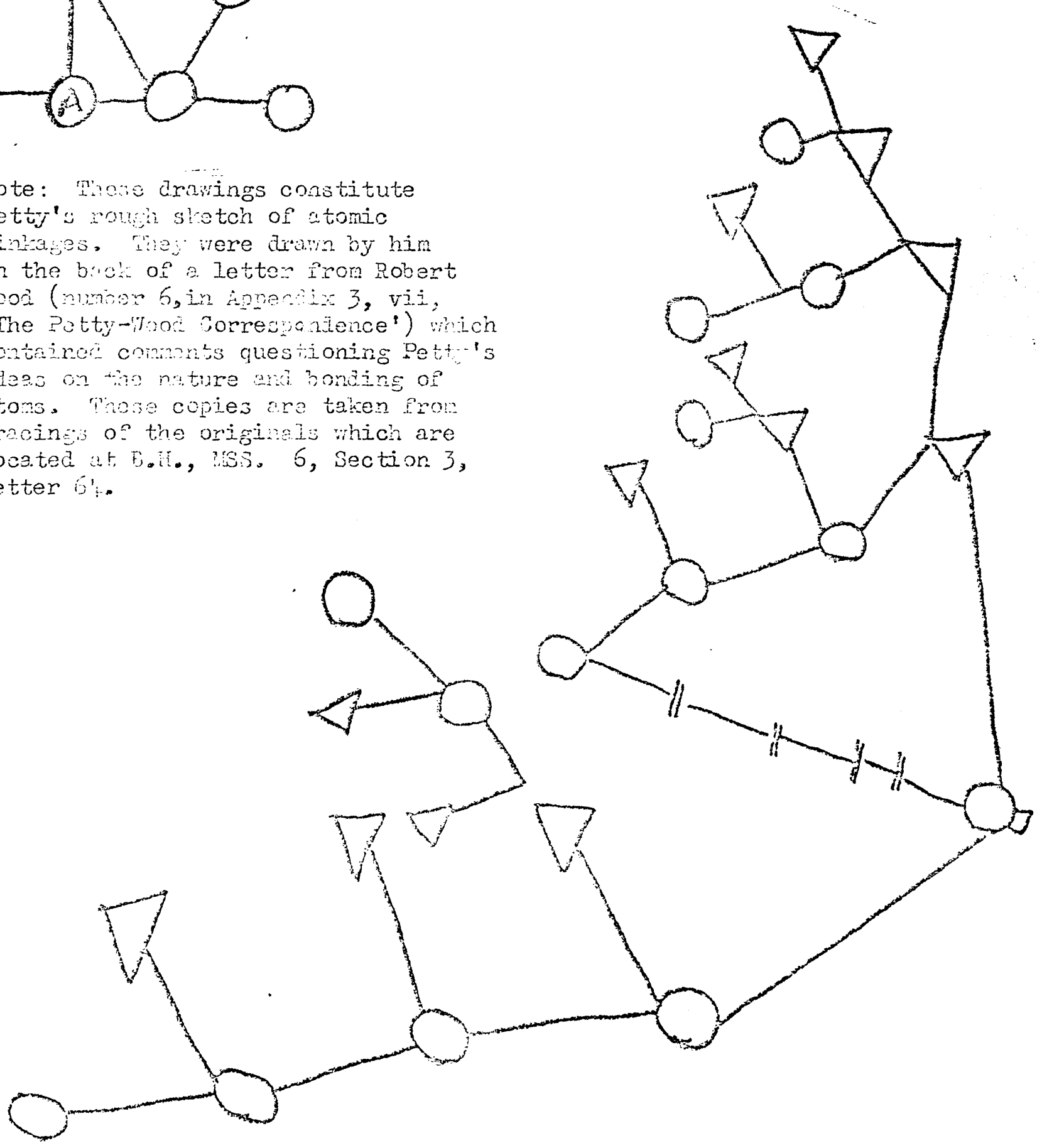
This puzzling aspect of the printed version of the Discourse has appeared to modern commentators either as an homogenous part of Petty's mechanistic theories,[3] or has been used to show that he was deeply influenced by the Hermetic tradition.[4] It would be misleading to suggest that Petty did not occasionally exhibit traces of Neo-Platonism and Hermeticism, especially when, in accordance with the nature of his continental education, such traces should be predictable. Nor should this trait be regarded as unusual, since comparison with other experimental philosophers such as Henry Power shows that it was relatively common.[5] Nonetheless,

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1. Petty, Discourse, pp.131-132. Petty maintains that this suggestion is to be taken literally and 'even without a Metaphor', ibid, p.130. Cf. Genesis: 1, 27.
2. For the Moschus legend see D.B.Sailor: 'Moses and Atomism', J.Hist.Ideas, 25 (1964), 3-16. For Newton see J.E.McGuire and P.M.Rattansi, 'Newton and the "Pipes of Pan"', Notes.Rec.Roy.Soc., 21 (1966), 108-143, especially, 130-132.
3. Cf. Kargon, 'William Petty's Mechanical Philosophy' op.cit., 65.
4. Cf. P.M.Rattansi, 'The Intellectual Origins of the Royal Society' Notes. Rec.Roy.Soc., 23 (1968), 129-168, especially 130-132.
5. For Power's eclectic attitude to mechanical philosophy see C.Webster, 'Henry Power's Experimental Philosophy', Ambix, 14 (1967), 150-178.







Note: These drawings constitute Petty's rough sketch of atomic linkages. They were drawn by him on the back of a letter from Robert Wood (number 6, in Appendix 3, vii, 'The Petty-Wood Correspondence') which contained comments questioning Petty's ideas on the nature and bonding of atoms. These copies are taken from tracings of the originals which are located at B.M., MSS. 6, Section 3, Letter 64.

in Petty's case it would be even more misleading to regard these elements as other than vestigial remnants of earlier attitudes, which later experience and lack of conclusive evidence had failed to eradicate. This judgment is partially substantiated by the fact that Petty introduced this section into the treatise immediately prior to publication. Since it was not included in the original discourse which he delivered as a paper to the Royal Society, it must be assumed that he intended it to fulfil a defensive role in the face of expected public criticism.[1] Thus, far from being an ingenuous statement of belief, this action suggests that Petty was prepared to accept the charge of inconsistency as the cost of establishing the sanctity and orthodoxy of his ideas.

Petty's view of the mechanical hypothesis was fully within the tradition which he had absorbed during his formative years on the continent. Allusion has already been made to the strong resemblance between his stress on the primacy of motion and that of Hobbes in 1645.[2] His particular view of atomism owed much to Gassendi, who had already termed the inherent motion of atoms 'gravitas', believed in a given number of variously-shaped particles, made no mention of the nefarious concept of indivisibility, and postulated that atoms possessed hooks (akin to Petty's theory of the 'Byass') which provided their corpuscular linkage.[3] Furthermore, by introducing concepts of magnetic and kinetic attraction, Petty also incorporated ideas which harked back to Gilbert and Kepler.[4] This

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1. See Appendix III, iii, Section 26, (ii).
2. Cf. Kargon, Atomism, pp.58, 68.
3. See R.B.Lindsay, 'Pierre Gassendi and Atomism' Amer.J.Physics, 13 (1945), 235-242; Kargon, Atomism, pp.65-68; B.Farrington, The Faith of Epicurus, (London, 1969), pp.111-118, 'Epicurean Physics'; O.R.Bloch, La Philosophie de Gassendi, Nominalisme, Materialisme et Metaphysique, (The Hague, 1971), especially 351-362; C.B.Brush, Selected Works of Gassendi, op.cit., pp.398-408; The diagrams opposite are Petty's illustrations of atomic bonding. While ill-defined, they show atoms linked in a triangular pattern of two poles and a central 'Byass'. These should be compared to Newton's illustrations in a letter to Boyle, 28 February, 1679, Newton Correspondence, op.cit., ii, 292.
4. Cf. Kargon, Atomism, p.69.

eclecticism provides a compensatory balance to Petty's strident claim to Henry More, in 1649, that he had totally rejected the 'Imaginary principles' of leading theoretical physicists and chemists in favour of the 'slibber-sauce' experiments beloved of Cornelius Drebbel. In less polemical moments, when his mind occasionally turned to subjects such as the mechanical philosophy, Petty was perfectly willing to synthesise ideas from a wide selection of natural philosophers.

Just as he had derived most of his thoughts on the mechanical philosophy from earlier innovators, so Petty shared an equally strong bond in the same field with many of his colleagues at the Royal Society in 1674. By this time the mechanical view of nature had been adopted in one form or another by many leading natural philosophers in England as the most persuasive hypothetical and explanatory model. The leading exponent of these ideas was undoubtedly Robert Boyle, and it was not coincidental that he subtly reaffirmed this belief in The Excellency of Theology compared with Natural Philosophy ... (1674).[1] The central portion of this work was a general discussion of natural philosophy and its subordinate function as an illuminant of the divine creation. In a highly sophisticated and complex fashion Boyle managed to extol the virtues of science without seeming to endanger the hegemony of religion. Then, in an Appendix, he delivered the most succinct description of his

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1. Cf. Fulton, Bibliography of Boyle, op.cit., pp.81-83. Boyle's work was reviewed by Oldenburg in Philosophical Transactions, c iii, (May 1674) 53-55. Previously, in his 'Prefactory Introduction' to Volume 6 of the Transactions, Oldenburg had said '... And if Modern diligence hath dived so deep as to find more satisfaction in Atoms, than in the three controverted Principles, will ... [Historians or Antiquarians] ... allow these Criticks to call the Atomical the New Philosophy? Or have our Modern Atomists done amiss in purging the old Atoms of Greece from the Heathenish Errors of Greece?' ibid, 2089. By 1674 he was more confident '... now that the Mechanical Hypothesis is sufficiently settled, and the right Methods of Inquiring are found out ...,' Philosophical Transactions, ciii (May 1674), 53. See Kargon, Atomism, pp.93-105, 158-163 and notes; Dijksterhuis, Mechanization, op.cit., pp.433-444 for Boyle's mechanistic theories.

corpuscularianism, a description which in many points was substantially similar to Petty';[1] both of them stressed that the two basic principles of matter and motion were capable of explaining all phenomena, yet that they remained the simplest devisable. Thus Boyle noted:

> 'iv. Neither can there be any physical principles more simple than matter and motion; neither of them being resoluble into any things, whereof it may be truly, or so much as tolerably said to be compounded. v. The next thing I shall name to recommend the corpuscular principle, is their great comprehensiveness ...' 2

while Petty stated:

> 'To Conclude, I hope I may say, that these my Principles, are Principles indeed; for there can be no fewer nor easier than Matter and Motion ... And ... I hope they solve all the Phaenomena of Elasticity, and, as I think, of Hardness, Fixedness, Tenacity, Fluidity, Heat, Moisture, and the rest.' 3

As a result of this commonly shared premise, both men necessarily believed that all secondary qualities were caused by the variable motions and shapes found in the smallest functional units in nature.[4] Both emphasised that if the mechanical analogy held good, then all phenomena must obey the same natural laws, and it should therefore be possible to investigate them by experiment and mathematical analysis on the macroscopic rather than sub-microscopic level. Thus Boyle's argument ran:

> '... for both the mechanical affectations of matter are to be found, and the laws of motion take place, not only in the great masses, and the middle sized lumps, but in the smallest fragments of matter; ... And though nature (or rather its divine author) be wont to work with much finer materials ... yet an

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1. 'Of the Excellency and Grounds of The Corpuscular or Mechanical Philosophy'. Oldenburg's review accentuated this section. Cf. Birch, History, iii, 134, for his account of its reception at the Society. Boyle's system shared common sources with Petty's, notably Gassendian and Cartesian physics.
2. Boyle, Works (1744 ed.) iii, 451.
3. Petty, Discourse, pp.132-134.
4. Compare Boyle, Works, (1744 ed.), iii, 451, column 2, with Petty, Discourse, pp.132-133.

> artist himself, according to the quantity of the matter he employs, the exigency of the design he undertakes, and the bignes and shape of the instruments he makes use of', is able to make pieces of work of the same nature or kind of extremely differing bulk, where yet the like, though not equal art and contrivance, and oftentimes motion too, may be observed ...' 1

And Petty's account agreed:

> 'Again, all the Motions I fancy in my Atoms, may be represented in gross Tangible Bodies, and consequently may be made intelligible and examinable'. 2

The main difference between the two was that Boyle avoided discussion of the nature of the primary particles which went to make up corpuscles and at this point condemned any attempt to introduce non-mechanical forces into a completely mechanistic world, apart from that which pertained to the omnipotence of the divine Creator.[3]

Beyond these commonly shared ideas it is clear that a significant polarity over the subject developed among other contributors to the Royal Society's programme in 1674 and 1675. On the one hand there were important scientists, such as Nehemiah Grew, and virtuosi, like Southwell, who were energetic and uninhibited supporters of atomism. In A Discourse ... of of Mixture[5] Grew described atomistic theories in a system which exhibited many close parallels with Petty's. Grew argued that indivisible, immutable,

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1. Boyle, Works, (1744 ed.) iii, 452.
2. Petty, Discourse, p.133.
3. Boyle, Works (1744 ed.) iii, 456, 'A Recapitulation:' 'For, if recourse be had to an immaterial principle or agent, it may be such an one, as is not intelligible; and however it will not enable us to explain the phaenomena, because its way of working upon things material, would probably be more difficult to be physically made out, than a mechanical account of the phaenomena'.
4. Boyle reiterated his views in a written contribution to the Society (1674). See Birch, History, iii, 144-153, 19 November: 'Experimental notes of the mechanical origin or production of fixedness, as opposite to volatility'. Cf. also Appendix III, ii. For the acceptance of atomism at the Society cf. T.M.Brown, 'The Mechanical Philosophy and the Animal Oeconomy' ... op.cit. pp.117-120.
5. Grew, A Discourse ... Concerning the Nature, Causes, and Power of Mixture, (London, 1675), especially pp.14-23. Cf. Appendix III, ii. This was read 10 December, 1674.

variously-shaped atoms are the fundamental materials of nature, that the atoms belong to various classes or 'Species', and that these classes provide the basic regularity underlying natural phenomena. These atoms, by combining in different groups, can produce an infinite number of different materials, just as different combinations of letters can produce an infinitude of different words. They can be joined physically in three ways, which are all described in geometrical terms. The system is completely mechanistic and as such: 'is grounded upon the notions of Sense, and made out Mechanically'.[1] Although they exhibit different emphases, with Grew laying greater stress on motion as a basic principle, the two schema are remarkably similar. Southwell for his part simply lifted Petty's entire system and advocated its wholehearted acceptance:

> '[there is] ... but one common element, which is immutable atoms, ... supposing, according to a late hypothesis, that every atom (like the globe of the earth, like magnets, and indeed the whole visible world) hath in it three points considerable, namely, two in their surface, which were called poles, and one within their substance, which hath been called brass ...' [2]

This was an unusually bold assertion by Southwell, given his normally cautious outlook and the atheistical overtones of atomism in 1675.

On the other hand John Evelyn, who produced one of the earliest vernacular popularisations of Lucretian atomism, openly avoided any discussion of fundamental theories in physics and chemistry when investigating utilitarian aspects of different soil types:

> 'I intend not to amuse this noble Audience, or myself with those nice enquiries, concerning what the real

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1. Ibid, p.45.
2. See Southwell's 'discourse concerning water', Birch, History, iii, 196-216, delivered on 8 April, 1675. Quotation ibid, 197.

> Form of that Body or Substance is, which we call Earth ... [when] reduced to its principles, as whether it be composed of ... Salts, Atoms, and Particles ... which have been the curious researches and velitations of our later Theorists: but content myself with that Body or Mass of Gleab, which we both dwell on and every day cultivate'. 1

John Wallis also circumvented the subject when deliberating on the nature and effects of gravity:

> 'If it be objected, That there be no such perfectly fluid Bodies; but that those which we call Fluides, are either made up of very fine, but disunited, Atoms (each having its own shape and figure, though very small) as the Atomists suppose; or at least in some degree Unctuous and Viscous: I will not dispute that point, as not now necessary: but only express what it is I mean by Fluid or Liquid Bodies, ... ' 2

It is therefore obvious that in 1674 and 1675 distinct concern for atomism and the mechanical philosophy was one feature common to many of Petty's colleagues at the Royal Society. The differentiating factor was founded on whether or not as individuals they believed it was productive to defend this approach in public. In the case of Boyle, Grew, Southwell and Petty the reaction was substantially in the affirmative. For Wallis and Evelyn, (the one because of vocational concerns, the other for social and political reasons) the response was cautious and hesitant. In accordance with these apprehensions, and as subsequent views on The Discourse of Duplicate Proportion bear out, the issue of

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1. John Evelyn, A Philosophical Discourse of Earth Relating to the Culture and Improvement of it for Vegetation, and the Propagation of Plants, etc. as it was presented to the Royal Society, April 29, 1675. Cf. Appendix III, ii. Evelyn was increasingly sensitive to the radical implications of such ideas. Cf. L.Sharp 'Timber, Science, Economic Reform' op.cit. T.Mayo, 'Epicurus in England', op.cit., pp.43-51; L.Sharp, 'Walter Charleton ...' op.cit., 336-7; Keynes, Evelyn Bibliography, op.cit., pp.42-44.
2. J.Wallis, A Discourse of Gravity and Gravitation Grounded on Experimental Observations (London, 1675), p.4. As Doctor of Divinity, Fellow of Exeter College and Savilian Professor of Geometry at Oxford, whatever his private opinions on atomism, Wallis could not afford the public notoriety of association with the subject.

atomism was the one which, above all others, drew the most bitter and caustic criticism from unsympathetic commentators, and which necessarily looms large in any review of the general response to Petty's treatise.

(g) Condemnation, Reaction and Praise

As soon as the Discourse had appeared in print the author proceeded to send copies to friends and acquaintances. To clear his mind about exactly who should receive these presentation copies, Petty jotted down two lists of appropriate names.[1] When the duplications have been omitted the total number of recipients comes to twenty. Among them were some well known devotees of the new natural philosophy including Seth Ward, Bishop of Salisbury, Viscountess Anne Conway, (the well known metaphysician and friend of Henry More), John Locke, Sir Robert Southwell, Edmund Waller and Sir Joseph Williamson. Of these, only Anne Conway was not an F.R.S. Other Fellows, who can only be described as 'occasional virtuosi', included George, Baron Berkely, Sir Henry Ford (a close acquaintance of Petty), George, Duke of Buckingham, John Copplestone (the Provost of Eton), and Richard Jones, Earl Ranelagh.[2] Further prominent recipients were Thomas Barlow, then Provost of Queen's College, Oxford, Thomas Belasyse, Earl Fauconberg (an early patron of Walter Charleton),[3] Lord Ogle, son of the Duke of Newcastle, and possible Sir John Winter, the wealthy iron-master. This list obviously represented

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1. B.M. MSS. 6, Section 3, Letter 64, f. 2r. The following have been conflated from the two lists: 'Falconberg, Ranalegh, Bp. Salisbury, Winters, Berkly, Ogle, Middlesex, Conway, Buckingham, Copleston, Barlow, Floyd, Ford, Harbord, Southwell, Lock, Waller, W[illia]mson, Henley H[ert]ford'. The ascription of names has been made on the basis of a recorded interest, often marginal, in the new philosophy.
2. For dates of Fellowship cf. T.Birch, History, ed., A.R.Hall, (Facsimile of the Edition of 1756-57, Johnson Reprint, New York and London, 1968) I xxxii-xlv. The library at Queen's College, Oxford, contains two copies of the Discourse: one probably belonged to Williamson and the other to Barlow. The copy shelfmarked N.N.f.90, contains Petty's holographic calculations on the back fly leaf.
3. For Fauconberg's relationship with Charleton cf. L.Sharp, 'Walter Charleton' op.cit., 332-333.

a group which was powerful and influential in society and politics. Although some of its members lacked serious scientific interests and attainments, they were nonetheless a potentially valuable asset for the ongoing defensive programme. In addition, copies of the treatise were also sent to Arthur Annesley, Earl of Anglesey, William Cavendish, Duke of Newcastle, Thomas Hobbes and Christian Huygens.[1] Finally, Petty sent ten copies to Ireland, of which some were allocated to obscure acquaintances, and others were distributed to Robert Wood, Arthur Capel, Earl of Essex (currently Lord Lieutenant), Sir William Temple, and Sir Richard Reynell, a judge of the King's Bench.[2] It is likely that Petty's criteria with regard to these Irish recipients depended on his desire to gain favour with some leading figures in the country, on his wish to keep interested colleagues advised of his latest ideas, and on his basic intention of defending and describing the work of the Royal Society. This list also indicates that groups and individuals associated in Dublin in the same way as their counterparts in Oxford, Edinburgh or Boston,[3] and that it was only out of such matrices that formal societies could develop.

As far as the wider availability of the Discourse is concerned, evidence suggests that the author paid scant interest in its distribution to the gentlemen and skilled craftsmen who would have been its main beneficiaries. Thus, although in a letter to Oldenburg of 28 July, 1675 Martin Lister referred to the work in a way which indicated its arrival at York, a year later John Beaumont, another rural correspondent of the

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1. For Annesley's receipt and transmission of his copy of 'L.M.' cf. Appendix III, v. Oldenburg sent the treatise to Huygens, 12 February, 1675, although Huygens subsequently failed to comment on it; cf. Ouvres Completes De Christiaan Huygens publiees par la Societe Hollandaise Des Sciences, (Hague, 1888-1950), vii, 1670-1675, (Hague, 1897), 416, letter 2009.
2. Cf. Letter from Petty to Waller, 19 January, 1675. B.H. MSS. 19, p.325: The full list included: the Lord Lieutenant, the Lord Chancellor, John Davies, Dr. Wood, Sir William Temple, Sir Richard Reynells, Sergeant Osborne, Mr. Ratlieff, Bishop March, Terence Coghlane, Mr. Davis and Bishop Vasey. For these figures cf. K.T.Hoppen, The Common Scientist, op.cit.passim
3. For the Boston Philosophical Society see R.P.Stearns: Science in the British Colonies of America, (Chicago, 1970) pp.155-156, and sources quoted therein. For the Oxford and Edinburgh societies cf. K.T.Hoppen op.cit. pp.210-211 and notes. The development of these institutions represents a lacuna in current historical knowledge.

Society, reported that he had been unable to see a copy.[1] In general, despite its small size and relatively inexpensive price of one shilling, it appears that Petty's lack of concern over wider distribution and a general lack of awareness or comprehension on the part of its intended audience, relegated this work to almost immediate popular oblivion.[2] As a result the treatise has never been reprinted and remains the author's most obscure book.

However, if there was a disappointing popular reaction to the Discourse, this was balanced for Petty by extensive criticism and comment from private correspondents and friends. The most bitter response came from 'L.M.', an acquaintance of the Earl of Anglesey. Although a variant of this letter was printed in 1693, by Sir Peter Pett, as the work of Thomas Barlow, and although it is known that he was aware of the book, circumstantial details suggest that this epistle was not from Barlow, who was then Lady Margaret Professor of Divinity at Oxford.[3] For example, apart from the fact that the two known manuscript copies of this letter are signed with the above initials, it is quite clear from the text of Petty's reply that the intermediary for both treatise and correspondence had been the Earl of Anglesey. In Barlow's case, however, we know from the list of presentation copies that he was one of the people who received the Discourse directly from the hands of the author. Furthermore, in the manuscript text of this acerbic commentary it is made clear that Anglesey had sent both letters and books to the querulous correspondent. Whereas it is known that Anglesey respected Barlow's erudition,[4] there is no

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1. For Lister's letter cf. Philosophical Transactions, cxvii (September 1675) 392, and for Beaumont's letter, dated Storey-Easton, Somerset, 17 June, 1676, ibid, cxxix, November 1676, 741-742.
2. See Boyle's comments on this problem in Usefulnesse of Experimental Naturall Philosophy, (1671) op.cit., 'The Preamble', Sig. *3v-Sig **r 'Secondly, it is not the Custome of Tradesmen to buy Books ...'
3. See Appendix III, v, 1 and 2.
4. Cf. 'Barlow' in D.N.B., for Anglesey's remarks, and his relationship with this cleric.

particular evidence that he usually sent large consignments of epistolary and printed material to the Provost of Queen's College, especially when such publications were probably available in Oxford by the time the parcel was despatched.[1] A more likely interpretation is that Anglesey had posted this material from England to one of his Irish friends who was, like himself, interested in the new natural philosophy. This friend, probably a cleric with a good working knowledge of radical and supposedly atheistical literature, could well have become acquainted with the author of the Discourse during one of Petty's prolonged stays in Ireland. Thus, while the evidence is unfortunately inconclusive, it would be unwise to argue that the letter necessarily represented either the view of Thomas Barlow, or the expression of general opinion at Oxford which was antagonistic towards some aspects of the Royal Society's outlook.

Whatever the exact origins of this letter, it did at least reflect the ideas of a section of contemporary society which was extremely hostile to certain proponents and tenets of the 'new philosophy'. As such its author attacked the Discourse from three different but related positions. Firstly, from a linguistic and philosopical point of view he made some caustic and perceptive comments about the 'Dictionary' of terms in the first chapter. In giving his own interpretation of this standard terminology Petty had adopted characteristics which were common to many seventeenth century philosophers. Like Hobbes he was intensely suspicious of words and desirous of being understood exactly.[2] His critic, believing in an external and absolute truth based ultimately on scriptural revelation, castigated Petty's Cartesian view of epistemology as being subjective and

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1. The book was in print by mid-January, 1675, cf. Petty's letter to Waller which reported the posting of ten copies to Ireland, BH. MSS.19. p.325.
2. Cf. The English Works of Thomas Hobbes, ed., Sir W.Molesworth, (London, 1839), iii, 23-25, Leviathan, 'Necessity of Definitions:' Hobbes maintained that the only science 'that it hath pleased God hitherto to bestow on mankind' was geometry. Using that as a paradigm Hobbes argued that exact definition must be the first step in any successful scientific procedure. See also ibid, xi, lxxi-lxxii.

at times almost whimsical. Thus Petty had defined place as 'the Image or Fancy of Matter, or Matter considered' and 'Motion [as a] change of Place'.[1] If this was so, said L.M., then since all 'Phansies are only in ye soul' to be in a place is to be in the mind. All external motion, which was merely a 'change of Place', was therefore a totally cerebral event. The logical result, concluded L.M., was that there could be no sure way of choosing between the Ptolemaic or Copernican hypotheses, and that to carry Petty's train of thought to its conclusion would lead only to the absurd denial of all external and objective truth. If the epistemological assumptions of Anglesey's correspondent are accepted, his attitude appears cogent and reasonable. Indeed, further evidence will show that he was not the only critic of these definitions, which undoubtedly suffered from imprecision and an occasional solecism.

Over the question of atomism the letter took a more emotional stance. Its author immediately associated Petty's christianised version of the mechanical philosophy with that of unreconstructed Epicurianism. For Anglesey's correspondent, 'Innate' atomic motion negated God's primacy in creating and running the universe and impeached the veracity of the book of Genesis.[2] Furthermore, atoms were either eternal or temporal, and L.M. quickly implied that Petty's account transgressed accepted doctrine by postulating atomic infinitude, thereby automatically denying God's eternal and infinite being. Even the idea that vast, but not immeasurable, numbers of atoms could exist in nature appeared preposterous.

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1. Petty, Discourse, pp.15-16. The author is grateful to A.J.Turner for permission to consult his paper: 'The Ashmolean Musaeum and the Historia Naturalis' delivered at Oxford in 1972. For Petty's use of preliminary definition in other subjects cf. Lansdowne, Petty Papers, i, 210-211, 'An Explication of Trade and its Increase : Definitions'.
2. This simplistic attitude was refined in the complex debate which raged in the 1680s over atomism. For this more sophisticated viewpoint cf. T. Creech, Titus Lucretius Carus His Six Books of Epicurean Philosophy. (3rd edn., Oxford, 1683). 'Notes', pp.1-14.

At the end of this section the letter returned to the fact that biblical accounts of the Creation failed to mention atoms, and that Aristotle had later established the inherent absurdity of such a concept. In castigating atomism this critic conflated all its proponents without any real differentiation, and attacked Gassendi, Epicurus and, by implication, Petty, with equal bitterness.

Only in its concluding paragraph did the letter reveal its author's basal, but predominant, fear that such 'Scepticisme' would rapidly weaken the fabric of Church and State by casting doubt on received dogma. This in turn would aid the efforts of England's most dangerous adversaries, namely, 'those of ye Roman faction'. Even worse, it was beyond comprehension that publications such as the Discourse could receive official sanction. In a world at war, argued L.M., each theological truth must be defended at any cost, if the effects of internal deviation and confusion were not to fragment the ideological solidarity of the State in the face of the Catholic conspiracy.

As on previous occasions, Petty's reply to this type of literary attack was unsentimental and forthright. In ironical vein he first prayed for the soul of his opponent, and admitted an inability to follow his arguments in all their intricacy. Having stressed once again the fact that his account agreed perfectly well with that found in Genesis, and having made reference to the famous Cartesian dialectic of 'Cogito, ergo, sum', Petty produced a spirited defence of some of the definitions included in his 'Dictionary' of terms. This exegesis, however, is not entirely convincing, if only because it employs exactly those linguistic techniques, whose use by scholastic philosophers Petty had earlier vehemently criticised. Nevertheless, his counter-attack became more credible when he turned to uphold the mutual compatability of atomism and orthodox religious dogma. God, argued Petty, was always immanent in a universe which only He was capable of creating. He was entirely respon-

sible for all motion and material interaction, just as He was entirely responsible for the composition of all matter itself. Furthermore, there was no reason why innate motion, which was also the crucial assumption underlying current theory on solar kinetics, should be any more atheistical than the universally accepted idea of innate heat. His critic was even more at fault for deliberately misinterpreting Petty's words. The defence was closed with a statement of bravado, to the effect that he had consciously restrained from subjecting his adversary to a more searching and scathing response.

The significance of this shrill debate is immediately apparent. Anglesey's correspondent failed to acknowledge Petty or the Royal Society by name, and he made no reference to the predominantly scientific, utilitarian and mathematical content of the book, probably because he regarded these as either neutral or benign elements in the new natural philosophy. Instead he singled out for attack those ideas which, for him and many others, seemed to presage the onset of atheism and the ultimate collapse of Church and State. For his part, Petty was genuinely grieved by what he saw as deliberate and unchristian misunderstanding, based on a false and prejudicial logic. Therefore, just as the controversy between More and Petty some twenty-five years earlier had revealed so accurately the tenor of some opposing views on the purpose of natural philosophy, so, in 1674, this debate highlighted similar issues in post-Restoration England.

But not all the comment aroused by the Discourse was as bitter and literary as this. The letters that passed between Wood and Petty during 1675 and 1676 indicate judicious cognisance on the part of the author's friend of the problems and methods covered by the tract. Historically, Wood's letters also reveal that he acted as advocate for other critical Irish readers of the Discourse, and they confirm that the level of numeracy among many senior government officials was remarkably low during the last

decades of the seventeenth century.[1] Furthermore, the evolution and nature of this correspondence is particularly revealing of the character and tone of debate among worldly, but well-informed, natural philosophers in post-Restoration England.

Robert Wood's criticisms and suggestions were expressed over three discrete but associated issues: the existence and nature of atoms and vacua, the author's troublesome definitions, and the mathematical applications and exactitude of Petty's use of duplicate proportion. As a mathematician, Wood could not agree with the concept of the indivisibility of basic units of matter, however small. This was a common attitude in contemporary critics, who also expressed disbelief in the concomitant principle that 'Vacuola, that is to say Nothings, [exist] wch yet must be supposed to have real properties of Length, Breadth and Thickness ...'[2] Obviously, the grounds on which Wood objected to atoms and the existence of vacua were totally different from those assumed by Petty's other major critic, and such objections reflect very clearly the different educational experience and predications of the three individuals. Furthermore, unlike other atomists such as Nehemiah Grew, Petty obstinately refused to adopt a palliative which accepted the theoretical divisibility of matter, while retaining a belief in the practical indivisibility of the atom.[3] His defiant approach pre-empted the alternative compromise, adopted by Boyle, of discussing hypothetical physics in terms of corpuscles, rather than irreducible units such as atoms.[4] Petty's persistent defence of

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1. Cf. Appendix III, vi, paragraph 3.
2. Ibid, item 6, paragraph 2. This was answered by Hobbes before he underwent conversion to the plenist hypothesis. For Hobbes in 1646 there was 'no impossibility, nor absurdity, not so much as an improbability in admitting vacuity ... for who knows not that Extension is one thing and ye thing extended another, as hunger is one thing, & that w^ch is hungry another'. Brit.Mus. Harley MS 3360, p.7. Creech also adduced strong arguments in favour of the vacuist theory, cf. Titus Lucretius Carus, op.cit., 'Notes', pp.11-14.
3. Grew, A Discourse of Mixture, op.cit., pp.14-15.
4. Boyle, Works (1744 ed.), iii, 455, Column 1.

atomistic concepts in successive letters therefore led to continued disagreement over this topic as a matter of principle. The impasse reached in Wood's penultimate letter was resolved only when he finally agreed to differ with his old friend:

> '3. That atomes and vacuola on one side, and Body infinitely divided on the other, are but severall Hypothesis. And (besides the metaphysicall reason ag^t vacuities heretofore hinted [at] the former seemes less curious or subtile etc ...' [1]

Secondly, Robert Wood took his illustrious correspondent to task over his definitions, especially those of 'Figure, 'Place' 'Quantity', 'Fancy' and 'Right'. Of these, Wood subsequently agreed to Petty's interpretation of 'Place' 'Quantity' and 'Right' once clarification had occurred. However, on clear geometrical grounds in the case of 'Figure', and on philosophical grounds with regard to Petty's Neo-Hobbesian use of 'Fancy', Wood maintained his unremitting opposition. As with the question of atomism, Petty also maintained his adamant stance over this logomachy, an indication that experience with Hobbes in Paris and of surveying techniques[2] in Ireland had indelibly printed these definitons on his mind.

Wood's third major criticism related to the mathematical techniques and instances given by Petty in the main body of the text. The first point was that of inaccuracy: some calculations were undoubtedly incorrect, and the description of certain problems was couched in imprecise language. Thus he questioned Petty's statement about mortality rates and different age ratios in the eleventh 'Instance', which had referred

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1. Cf. Appendix III, vi, 7, paragraph 3.
2. For the similarity between Hobbes's use of the word 'Fancy' and that of Petty, cf. Brit. Mus. Harley MSS. 3360, f. 3r, 'that Light is a fancy in the minde, caused by motion in the braine ...'. Petty, Discourse, p.14, 'But presuming you all understand, conceive, imagine, or Fancy the words Matter and Thought, as well as any other I can use ...'; and p.15. '1. Place is the Image or Fancy of Matter, or Matter considered ...' For Wood's criticisms see AppendixIII, vi, item 2, paragraph 3; item 5, paragraphs 1 and 3; item 6, paragraph 3; item 7, paragraph 2.

to the population levels of a parish well known to the author.[1] In fact, Wood proved willing to accept these statistical pronouncements as reasonable, and sometimes as proven once the inaccuracies were tidied up. To Petty's entirely typical comment that 'Polishing is not my way', Wood replied:

> ' 'Twere unfit so good an Architect should be employed in hewing of Stone or rubbing Bricks, yet even that inferior worke (w^ch^ may perhaps be done by others who would be glad of such employment) ought not to be neglected'. 2

Beyond this he was unyielding. He could not agree with Petty that sonic, odiferous and visual phenomena acted on the basis of the square rather than the cubic root. In Wood's view this resulted from their operation within a three-dimensional, rather than a two-dimensional, context. Again, Petty refused to concede the point, and the matter remained unresolved with both natural philosophers agreeing that the problem was hypothetical and not amenable to immediate proof.

It should not be imagined, however, that Robert Wood's response to the Discourse was entirely critical. On the contrary, he expressed a growing willingness to accept some of Petty's examples of duplicate proportion. Thus he reported in April, 1675 that:

> '... all my Corrections were not so serious ones as you might see by ye very first [letter]. I am so much in love with yo^r^ second instance that I would have it crown'd with a Garland or Corrolarie ... 'The Strength of like Timbers etc is in proportion to their respective surfaces, viz. as surface to surface, so strength to strength...' 3

In addition to this enthusiastic support, Wood also underlined his belief in the 'usefull Applications' of the technique, thus firmly link-

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1. As did Gregory King, cf. Chapter 4, p. 374 below.
2. Cf. Appendix III, vi, item 5, paragraph 4.
3. Ibid, paragraph 4.

ing himself to the tract's Baconian purpose. In conclusion, the correspondence reveals that these two colleagues responded to scientific problems in a way entirely consonant with their earlier intellectual experience. Wood's approach was derived from an acute geometrical perception, allied with a utilitarian/ism that remained essentially unaffected by continental attitudes to hypothetical physics. Conversely, Petty's viewpoint was in keeping with his broader mathematical and scientific training and his more creative, but sometimes less exact, attitude to natural philosophy. One final observation is that, as a result of this exchange of views, neither man suggested or undertook further experimental verification of the mathematical principles enunciated in the treatise. In comparison with Mersennes' work on sound, Newton's investigation of light or Hooke's experimental study of elasticity, this must appear a weak link in their scientific method.

Beyond these more immediate responses the Discourse of Duplicate Proportion stimulated reactions from nautical experts. In the first instance, Samuel Fortree gave a brief but significant analysis of the book in the manuscript treatise 'Of Navarchi', which he sent to Samuel Pepys.[1] Here, Fortree discussed many subjects relating to naval architecture, for which Pepys, Deane and Petty shared a common interest. Referring to the 'ingenious author of the duplicate proportion' Fortree developed the point that the resistance to a ship's hull at a speed of '2x' is at minimum likely to be equal to the square of the resistance at Speed 'x' because:

> 'In a vessel saileing in the water ye opposition of the medium will require a continual succession of reaction after ... And where the velocity is doubled the opposition will also proportionally be increased; whereby a quadruple force may be necessary for a duplicate celerity'. 2

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1. Magdalen College, Cambridge, Pepys MSS. 1731: 'Of Navarchi', cf. J.R. Tanner, Bibliotheca Pepysiana, (London, 1914), p.5.
2. Pepys MSS. 1731, p.29.

However, due to the fact that, as the boat increases its speed, so the increase in the wind's effective force diminishes with the corresponding forward motion of the mast:

> '... The force is lessen'd in proporcon as the motion of the ship is increased ... So as to supply that defect an addition or saile must be made proportionable which may require 1/3 more; so as not only a quadruple saile, but a sixduple saile may be necessary for a duplicate celerity'. 1

Fortrese also hinted that resistance and force might be related according to variable rather than fixed ratios, positing that Petty's argument

> 'for proof offers the square root as a rule to determine ye proportion of all degrees of velocity. But that rule doth not seeme to be certaine in all cases; ffor that both the Medium as also the impellant force may often differ'. 2

It is therefore significant that whereas Petty's work with water tanks and models was much more extensive than this author's supine attitude to experimentation, Fortree's understanding of some mathematical problems in hydro-mechanics was more acute. It is equally significant that in later years Fortree apparently made no effort to test the validity of his theories by controlled experiments.

A later, but this time published, contribution to the subject appeared in Sutherland's Ship-builder's Assistant[3] in 1711. This classic instructional text on naval architecture can be regarded as a natural development following the work of Wallis, Pett, Deane, Petty and Newton. Its author was that rare combination of skilled artisan, erudite bibliophile, numerate natural philosopher and cogent author. To this admirable mixture

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1. Ibid, p.30.
2. Ibid, p.29.
3. W.Sutherland: The Ship-builder's Assistant, (London, 1711). See pp. 1-4 and 23 for the principal scientific sources, which included Plato, Acontius, Galileo, the famous Harris Dictionary and Hayes' work on fluxions. Sutherland's work was still valuable in 1794, when another edition was published.

of qualities was added distinguished organisational ability and a highly developed skill in draughtsmanship. As a product of one of the great seventeenth century English dockyards and an established shipbuilding family, Sutherland was fully schooled in the craft aspects of naval architecture, and was equally concerned with practical, as with theoretical matters. Yet he was also aware, from his knowledge of the work of leading natural philosophers, that any real 'improvement' of ships and ship-design could only come through the application of scientific methods:

> 'And the Benefit that will follow to Shipping from such [theoretical] Observations will be infinite. First, The Art will be made perfect, that there will be no Occasion for chargeable or fruitless Projects. Secondly, Ships will not by bad Faculties miscarry, since it may be absolutely known whether they are for Service or not ...' 1

It was within this context that Sutherland made reference to the Discourse. Having already discussed with great clarity the basic (Galilean) laws of the strength of materials, and having illustrated these theories with the aid of diagrams, Sutherland outlined one way in which this knowledge could be vital to shipbuilders. Following 'Sir William Petty, in his Book of Duplicate Proportion' he showed by calculation that large ships were usually built with an almost excessive margin of integral strength. Thus, concluded Sutherland, ' ... finding the largest Ships are sufficiently strong, it must follow that the small ones are over-timber'd'. By avoiding this problem a great deal could be achieved:

> 'And if it can (as I doubt not but it may) be easily proved, that a Sixth Rate may be built as strong, and performed as well every way with half the Timber; the Benefit will not be only in that Particular [sic], but in the Masts, Sails, Rigging

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1. Ibid, p.4. See also p.27 for a further statement, that only by the application of scientific principles could the uncertainties of nautical design be eradicated.

> and Blocks. The Men will be also lessen'd, and every particular part of the Equipping reduc'd; so that three Ships will be then built for the Charge of two now'. 1

In a later chapter Sutherland described a method which aimed to develop the concept in practical terms.

This work therefore provides evidence that Petty's book was not totally forgotten by the end of the century. Indeed, it shows how his ideas could stimulate further productive thought on some important technical problems. Undoubtedly, Sutherland's book was far more comprehensive as an organised instructional text than had been the Discourse. Still, as a beneficiary of earlier work by prominent natural philosophers, Sutherland possessed a great advantage over Petty. It cannot be doubted that this early eighteenth-century synthesis reinforces the claim that English scientists in the later seventeenth century made significant advances in various technical fields, and that these contributions were sometimes effectively bequeathed to subsequent investigators.

Another important comment on Petty's treatise came from Hobbes. In a letter to Aubrey, Hobbes noted his receipt of the Discourse which had accompanied Aubrey's previous letter:

> 'I pray you remember my Service to him, if you see him, and tell him that if I had seen his booke before it went to presse I would not (as he thinks) have hindered it, but done as the Society did, that is urg'd him to print it, for the doctrine is easy to be demonstrated. The Last Chap: which is of Elasticity is different from the Principle which I have taken for Naturall Philosophie: but I am of the opinion that his supposition is very true, and will goe a great way'. 2

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1. Ibid, pp.33-34.
2. B.M. MSS. 6, Section 3, Letter 17.

This was one of the few occasions when Hobbes openly awarded praise to the work of a contemporary author. As we have already seen, Petty's attitudes were profoundly influenced by his short but intensive work with the great philosopher during 1645 and 1646. For example, in Petty's theoretical physics the concept of motion later played a major role, just as it had already in Hobbes's optical treatise, completed during the period of their association in Paris. Again, Petty's concern for definition, and his use of words such as 'Fancy', were undoubtedly drawn from an earlier authoritative usage by Hobbes.[1] Yet, while there were significant similarities between their attitudes (as outlined by a recent commentator)[2] there were also important differences. Furthermore, in the very letter quoted as evidence for this claim of almost unreconstructed derivation, there is unmistakeable evidence that both men were aware of subtle but significant differentials.

Thus Hobbes mentioned Petty's fear that his old mentor would hinder the book's publication, though as it happened this was completely unfounded. Still, Hobbes himself pointed out that the principles on which Petty based his mechanistic theories differed on such matters from his own ideas. Of course the crucial question is why Petty should have imagined that Hobbes would wish to suppress the book. This must have originated from the latter's stringent attitude to the deliberate pursuit of profitable, utilitarian applications in natural philosophy. As Hobbes had said in the treatise on optics:

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1. See above, page 215 , and notes.
2. Cf. Skinner: 'Thomas Hobbes and his Disciples in France and England 'Comparative Studies in Society and History, 8 (1965-1966), 153-167, especially 165. Dr. Skinner is not precise about Petty's debt to Hobbes, and while he allows that their views were 'analogous' and that they shared 'affinities', he also regards Petty as one of Hobbes' 'disciples'. This is incorrect, since Petty's view of mathematics and natural philosophy differed consciously, and markedly, from that of Hobbes. Cf. Hull, Economic Works, i, lxi-lxii, on Hobbes and Petty as economists.

> '... which makes mee, when I heare a man, upon the discovery, of any new and ingenious knowledge, or invention, aske gravely that is to say scornefully, what tis good for, meaning what monie it will bring in, (when hee knowes as little, to one that hath sufficient, what that overplus of monie is good for) to esteeme that man nott sufficiently removed from brutalities ...' 1

Hobbes did not have a high regard for those natural philosophers who pursued the lucriferous, rather than the luciferous, aspects of their work, and inevitably his comments on the Discourse related more to the question of basic theoretical physics than to the useful applications of duplicate proportion. Most likely, therefore, Petty feared that Hobbes' response to such applications would have extended to harsh antagonism, especially since his career and attitudes exhibited a financial success which the older man abhorred. The relationship between Hobbes and Petty over the Discourse is thus complex and variegated. Each esteemed the other, and each looked at certain problems from a broadly similar point of view. Both were prominent advocates of radical ideas and both gave little thought to the unavoidable notoriety which such radicalism caused. Both agreed that over the particular question of the mechanical philosophy their different principles were equally valid in a theoretical sense, and would, in Hobbes's words, 'goe a great way' to explaining the phenomena. Neither made a thorough experimental check of these theories. Yet the fundamental axis of Petty's thought as expressed in the Discourse,(mathematical but not essentially geometric: more utilitarian, but less abstract and less rigorously logical) was in the end different from, and at points anti-thetical to, that of Hobbes.

The final evidence of this wide range of reactions to Petty's book comes from other scattered contemporary sources. Some of these are

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1. Brit. Mus. Harley MSS. 3360, f.2v. Hobbes had already stated his contempt for what ' ... in men is called Avarice, For desire of knowledge, and desire of needlesse riches are incompatible, and destructive of one another ...'

associated with another of Petty's close friends, John Aubrey, who, as we have already seen, was responsible for Hobbes' initial interest in the Discourse.

Although Aubrey was never an innovative or particularly skilled mathematician, he was aware from an early age of the central part that various mathematical traditions played in the development of natural philosophy. Thus, manuscripts show that by the 1650s he was earnestly studying mathematics, and was accepting instruction from his more erudite friends with humility and gratitude.[1] It is therefore not surprising that, when he later came to formulate his own didactic programme in 'An Idea of the Education of young Gentlemen',[2] he made frequent reference to the works of his admired friend, Sir William Petty. Naturally enough, when covering mathematical education Aubrey included the Discourse of Duplicate Proportion in his list of required reading,[3] and occupied two pages of the manuscript of his 'Idea' with exercises on the method embodied in the treatise, as provided by another learned mathematician, Nicholas Mercator.[4] It is quite clear that Aubrey viewed the utilitarian and the disciplinary value of mathematical training from a position close

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1. Cf. two volumes of Aubrey's collected mathematical manuscripts at Worcester College, Oxford: MSS. 4.9 (No.83) and MSS. 5.5 (Nos. 64 and 64A). These reflect Aubrey's lifelong interest in mathematics and contain exercises, notes and texts provided by Pell, Wallis, Collins, Mercator and Barrow. The earliest date recorded is in MS. 5.5, where Edward Davenant's text on algebra has been marked by Aubrey as: 'Eaton-Pierse Wittes, 1659'. MS. 4.9 contains Gunton's 'Arithmetica Decimalis' which deals, like Oughtred's Clavis, with the doctrine of proportion. For Aubrey's mathematical interests cf. M.C.W.Hunter, op.cit. pp.43-50.
2. This treatise is Bodleian Library, Oxford, MS. Aubrey 10. A defective edition has appeared: Aubrey on Education. A hitherto unpublished manuscript by the author of Brief Lives, ed., J.E.Stephens (London, 1972), whose only value is to provide an indication of the contents of the manuscript.
3. For Aubrey's reference to the Discourse cf. J.E.Stephens, op.cit., p.103.
4. See MS. Aubrey 10, f 43 r + v. 'Sir W.Petty's Duplicate proportions: donne by my learned friend Mr. Mich: Mercator'. The exercises covered the variable range of sounds from cannon fire, pendular vibration and the differing ranges of cannon shot, which depended on variation in the amount of propellant material. For Mercator see D.N.B. and E.G.R.Taylor, op.cit. pp.222 and 391. Mercator was a leading exponent of applied mathematics during this period.

to that of Petty, though it is also true that Aubrey gave a far more comprehensive description of the elements which he felt should make up the optimum course in this subject. Nor did he easily forget Sir William's diminutive treatise, for Petty's letter of May 1678 indicates that Aubrey had again raised the issue of the book's critical reception.[1] This also reveals that Francis Lodwick, an old associate from Petty's pre-Oxford days, was in the process of transcribing the book into the 'Real Character' or universal language of John Wilkins. Once again the common bonds of utilitarianism and a broad view of what, for many, constituted contemporary natural philosophy are reaffirmed by this remark.

As well as Aubrey's admiring comments, Petty received a crop of testimonials praising the Discourse. In response to the dedicatory letter, published at the beginning of the book, Petty was sent a short but almost fulsome note by William Cavendish, Duke of Newcastle. In this letter Cavendish accepted the dedication with pride 'Since Itt came from so worthy a person as youre selfe ...'[2] Finally, another epistle redolent with praise was received from a friend signing himself 'Franckilmore'. Here, the correspondent revealed himself to be a classic seventeenth century virtuoso, with all the frailties of that particular intellectual species:

> 'S^r. I am much better Pleased with the favour you conferred upon me by directing yr discourse to the R. Society, to me than if you had sent me Suarez or de Thomy ... I live among Plowmen and Cow pastures, where Philosophy 'tis true is present and finds as much to doe as in Cittyes but she lyes incognito, but when yo^r discourses arrive she crows in triumph and makes a stately entrance, and I should be glad to honour her an her Receptione ...' 3

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1. Cf. Appendix III, vi, item 3, paragraph 1.
2. B.H. MSS. 6, Section 3, Letter 59, dated 27 February, 1675. A fragmentary draft of Petty's reply to Newcastle is located at Ibid, Letter 20.
3. This epistle, which is almost illegible, is at B.H. MSS. 6, Section 3, Letter 66, and is dated 3 July, 1675. See also, Lansdowne, P.S.C., pp.163, 169 and 308 for reactions from the Southwell family to the Discourse.

The wide range of response to Petty's Discourse of Duplicate Proportion shows that this small and moderately obscure treatise excited the attention of many contemporaries interested in, or directly involved with, natural philosophy. Their letters and comments are most informative about the environment and opinions which surrounded this expanding field in the later years of the seventeenth century. This evidence proves that a multiplicity of attitudes could exist simultaneously, and that these were often a complex amalgam of common traits and unique idiosyncrasies. It shows that opinion within, and without the world of natural philosophy failed to divide along unbroken lines of opposition or support. On the contrary, it was variegated at all levels and over many issues, and only the most insensitive of analytical methods could fail to reveal this fundamental characteristic.

In terms of Petty's own intellectual development, and the basic homogeneity of his thought, the Discourse proves that the apparently fragmented components of mathematics, technology, economics and theoretical science in reality operated within a cohesive intellectual framework. And while there were undoubted flaws in this structure, as there were methodological weaknesses in the Discourse and in Petty's subsequently restricted experimental work, so there were important and creative strengths. Thus his attempts to broaden the role of mathematics, to search for Laws and regularities behind the most diverse phenomena, were significant contributions to the progress of contemporary natural philosophy. So too was his awareness of the need for new syntheses of technical and mathematical procedures, and his almost prophetic sensitivity to the potential of the inverse-square law.[1] Also the Discourse of

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1. For the importance of this relationship to Newton's solution of planetary kinetics, cf. Hall, Galileo to Newton, op.cit, pp.286-288. Further instances of the application of this formula to hydrostatics by Newton, Marriotte and Halley are in E.MacPike Papers and Correspondence of Halley, op.cit. pp.147-148. See also J.A.Bennett 'Hooke and Wren and the System of the World' op.cit., 33-34.

Duplicate Proportion establishes a firm and natural link between the heroic technological exploits of Petty's youth, and the development later of statistical and socio-economic perceptions which provided the basis for his pioneering vision of political arithmetic. It unarguably links Petty the surveyor, doctor, and improver, with Petty the empirical social analyst and reformer.

However, with regard to the scope, method and intended function of the Discourse itself, the final word should rest with the author, who, for all his occasional lacunae, was still capable of perceptive self-examination:

> '... Carpenter's and Wheelwrights say that the diameter is to the circle as 1 to 3. Others say better as 7 to 22, but neither is exact, yet both serve their turne. So what I have done in that discourse was only to keep men from grosse errors and for bringing them into the way of exacter truth. I hope no man takes what I say'd about the mocon and burthen of horses and the living and dying of Men, for Mathematicall demonstracon, Yet, I say they are better ways of estimating these matters then I ever heard of from others. I hope better are now found out, But there are 2 or 3 real mistakes in that treatise of which more with ye next ...' 1

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1. Petty to Aubrey, 29 May, 1683. See Appendix III, vi, 8 for the complete text.

Chapter 4

Political Arithmetick, Political Anatomy and Political Algebra: The Pursuit of Geometrical Justice

'For, my Lord, there is a Political Arithmetic, and a Geometrical Justice to be yet further cultivated in the World; the Errors and Defects whereof, neither Wit, Rhetoric, nor Interest can more than palliate, never cure. For, Falsity, Disproportion, and Inconsistence cannot be rectified by any sermocinations ... Nam Res nolunt male administrari'

Discourse Concerning the Use of Duplicate Proportion, sig.A 10v - A 12r.

'[Lord Bacon] saies: The writings of speculative men upon active matters (for the most part) seemes to men of experience to be but as dreams and dotage: And that it were to be wished (as that which would make Learning indeed solid and fruitfull) that Active men would or could become Writers'.

R.Austen, A Treatise of Fruit Trees (Oxford, 1657) Sig. b.1.

'By Political Arithmetick, we mean that Art of Reasoning, by Figures, upon Things relating to Government.
The Art it self is undoubtedly very ancient; but the Application of it, to the particular Objects of Revenue and Trade, is what Sir William Petty first began, who as yet has been follow'd by very few: He first gave it that Name, and brought it into Rules and Method; and his excellent Wit would have carry'd it very far, if he had liv'd to this time; for his skilful Hand did all along want right Materials to work upon, with which he might have been furnish'd, by the variety of new Taxes that have been lately levied in this Kingdom'

C.Davenant, Discourses on the Publick Revenues, and on the Trade of England, (London, 1698), p.2.

(a) Political Arithmetick and Political Anatomy:

A prominent feature of outstanding intellectuals is their ability to excite heated controversy. Petty provides a good example of this phenomenon. On balance, sheer numerical weight has swung the debate in his favour. However some pertinent observations have been made about the inaccuracy of his method which raise serious doubts about the credibility of his entire approach. Despite obvious disagreement over Petty's intellectual status, participants in this prolonged discussion have generally accepted that its focal points are his passion for mathematical analysis of socio-economic data and for those plans which naturally resulted from such 'ratiocination'.[1] A brief account of these exchanges will help to identify the historical principles and antecedents which induced such partisan support.

Soon after his death, Petty's exercises in political arithmetic were subjected to searching criticism by younger colleagues. With some justification, Gregory King asserted in his journal that Petty's estimate of world population was too low, since he 'endeavoured to magnify England [and] so lessened ye World and other Countries'.[2] In this judgment King agreed with Davenant who commented 'for which Reason [i.e. patriotic self interest] we have ground to suspect, [that] he rather made his Court,

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1. Essential comment on this controversy is given by S.Matsukawa, 'Origins and Significance of Political Arithmetic', Ann. Hitotsubashi Acad., 6 (1955), 53-79. See also, W.H.Greenleaf, Order, Empiricism and Politics 1500-1700, (Oxford, 1964), especially pp.227-230, 249-261; E.A.Johnson, Predecessors of Adam Smith (London, New York, 1937), pp.93-113; A.Wolf, History of Science, Technology and Philosophy, op. cit., ii, 582-628; P.F.Lazarsfield 'Notes on the History of Quantification in Sociology - Trends, Sources and Problems' Isis, 52 (1961), 277-305; Sir G.Clark, Science and Social Welfare in the Age of Newton, (sec.ed., Oxford, 1970) pp.113-146; C.Wilson, England's Apprenticeship, op.cit., pp.226-236; Hull, Economic Works, i, xxxix-lxxix; Lansdowne, Petty Papers, i, xxvii-xxxix; ibid, ii, 273-282; Strauss, Sir William Petty, pp.173-224; L.Hogben, Political Arithmetick (London, 1938), pp.13-33.
2. G.King, 'The L.C.C.Burns Journal' in ed., P.Laslett, The Earliest Classics (1973, Gregg International) unpaginated, 'Of the number of People in ye World a ° 1695'. King was criticising Petty's Political Arithmetic, (London, 1691). For King cf. D.V.Glass, D.E.C.Eversley, Population in History, (London, 1965), pp.159-220.

than spoke his Mind'.[1] Later, Adam Smith delivered the famous remark: 'I have no great faith in political arithmetic', when discussing the possibility of making accurate estimates about British trade.[2] More recently, Petty's demographic work has been criticised by Professor Willcox, the eminent American statistician, on the grounds that 'To the trained reader Graunt writes statistical music: Petty is like a child playing with a new musical toy which occasionally yields a bit of harmony'.[3] This description of Petty's psychology and method as child-like was vigorously supported by Greenwood in his authoritative history of medical statistics.[4] Even Petty's claim to be the originator of political arithmetic has been questioned by Letwin, in an essay both provocative and acute,[5] where he notes that 'seldom can a writer have said so much about his method of work and still had time for the work itself', and characterises political arithmetic as 'a rhetorical device', and a 'vainglorious dream' which was inaccurate, naive and entirely worthy of Swift's brilliant satire, A Modest Proposal.[6]

Against these varied, but generally critical judgments must be set those which accentuate the strength, rather than the weakness, of Petty's work. Davenant's ambivalence has already been shown in the quotation which prefaces this chapter. Less hesitant was Arbuthnot's summary:

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1. Davenant, Discourses, op.cit., p.6, 'Of the Use of Political Arithmetic'.
2. Quoted, Clark, Science, Social Welfare, op.cit., pp.144-145.
3. Quoted, Laslett, Earliest Classics, op.cit., Introduction.
4. Major Greenwood, Medical Statistics from Graunt to Farr (Cambridge, 1948), pp.13-14.
5. W.Letwin, The Origins of Scientific Economics, English Economic Thought 1660-1776 (London, 1963), pp.114-146, 'Sir William Petty; Political Arithmetick', especially pp.128-140. See also Letwin's hostile review of Strauss, Sir William Petty, in J.Polit.Econ., 64 (1956), 180-181.
6. See G.Wittkowsky 'Swift's Modest Proposal : the Biography of an Early Georgian Pamphlet', J.Hist.Ideas, 4 (1943), 75-104; J.Swift, A Modest Proposal (Dublin, 1729) in ed., H.Davis, Swift's Prose: xii, Irish Tracts, 1718-1733 (Oxford, 1955) xviii-xxi, and 109-118.

> 'Arithmetic is not only the great instrument of private commerce, but by it are (or ought to be) kept the public accounts of a nation; I mean those that regard the whole state of a commonwealth, as to the number, fructification of its people, increase of stock, improvement of lands and manufactures, balance of trade, public revenues, coinage, etc. ... This is the true political knowledge ... What Sir William Petty [has written] in political arithmetic, does abundantly shew the ... usefulness of such speculations. It is true, for want of good information, [his] calculations sometimes proceed upon erroneous suppositions; but that is not the fault of the art. But what is it the government could not perform in this way, who have the command of all public records?' 1

In the nineteenth century, Marx and Engels made frequent reference to Petty's theories; when discussing his analysis of certain economic problems Marx noted 'After thus explaining <u>rent</u> ... and its expression in money, he [Petty] then sets out, again in a brilliant way, to determine the <u>money value of land</u>'.[2] Petty's schemes for the rebuilding of London also received praise from Brett-James, the capital's historian:

> 'Seldom have there been men more prolific in ideas for London's welfare than there were after the Fire, and Petty was among the most original of his age ... If [his] schemes had been studied and altered where necessary, most of our modern problems in the suburban areas need never have arisen'. 3

In the view of a recent historian of American demography, the enumerative projects which dominated Petty's later years were equally remarkable.[4] Even modern econometricians have detected outstanding elements in his work. Thus Clark prefaced his analysis of the distribution of labour in contemporary industries with the comment that:

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1. <u>The Life and Works of John Arbuthnot</u>, ed., G.A.Aitken (Oxford, 1892), pp.421-422, 'On usefulness of Mathematicall Learning' (1701).
2. K.Marx, <u>Theories of Surplus-Value (Vol.4 of Capital)</u>, (Moscow n.d.) p.347. See also Engel's edition of <u>Capital</u> (London, 1896), pp.64, 75, 98, 119, 302, 340, 359 (notes).
3. Brett-James, <u>Growth of Stuart London</u>, <u>op.cit.</u>, pp.321, 324.
4. J.H.Cassedy, <u>Demography in Early America: Beginnings of the Statistical Mind, 1600-1800</u> (Harvard, 1973), p.51.

> 'It is sufficient to say that most of the world remains quite unaware of the significance of Petty's brilliant and entirely correct generalisation from the scanty facts at his disposal in 1691; and that many concerned with economic policy still act as if they, too, were entirely unaware of what might be called, in all fairness, Petty's Law'. [1]

The preceding remarks show that a state of confusion currently prevails as to the nature and value of Petty's socio-economic thought. This is mainly attributable to the fact that 'our view ... depends to a large extent upon the kind of windows that we look through'.[2] In other words, the preconceptions of those interested in Petty have dictated their attitude to his work, and have often distorted their accounts to a lesser or greater degree. Although it is impossible for an historical analysis to escape the epistemological impasse inherent in its selective procedures, this problem can be minimised by a clear delineation of assumptions, careful contextual reference, and an awareness of the organic structure of the subject's ideas.

Ultimately, statistics are compiled because it is believed that quantitative knowledge will be useful in shaping policy: the type of information required will depend on prevailing social and economic concepts. Once obtained, this information becomes an integral component of ideas and policies. As a result statistics are, historically, always both a product and a determinant of attitudes and actions.[3] In Petty's case, examination of his proposed methods of data-gathering and his statistical treatment of certain subjects should reveal the nature of those products and determinants, facilitating rational assessment of

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1. C.Clark, The Conditions of Economic Progress (London, 1951), pp.395-396; this section was expanded in the 1957 edition, cf. pp.492-493.
2. Johnson, Predecessors of Smith, op.cit., p.97; For a lucid discussion of this factor cf. J.D.Chambers, Population, Economy and Society in Pre-Industrial England (London, 1972), pp.1-7.
3. This statement paraphrases that in G.N.Clark, Guide to English Commercial Statistics 1696-1782, (London, 1938), pp.ix-x.

his ideas. However the full significance of these concepts will only become evident once the central role of statistics in the modern world has been examined.

After a century and a half of rapid development,[1] techniques supplying enumerated social and economic data have become the common basis for most governmental decisions. These methods of collection, quantification and analysis are now regarded as essential for effective control of any society, whether it resembles American 'free-market capitalism', follows the centralised pattern of Eastern-bloc communist countries, or is a member of the impoverished group described as the 'fifth world' (e.g. underdeveloped countries like Ethiopia, Mali, Afghanistan).[2] Manipulating and honing these analytical tools are specialists who supposedly combine the power of priest, seer, mathematician and empirical scientist in a single function. Contemporary acolytes of this priesthood are the statisticians, demographers, econometricians, actuaries, sociologists, biometricians and historians, who collect and interpret arcana on which current governmental and political decisions are based.[3] Unfortunately, their deliberations have helped spread an improvident mythology among non-initiates, which is expressed in a simple-minded acceptance of conclusions based on seemingly self-evident data. Despite proper cynicism over the value of such statistics, and

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1. Cf. M.J.Cullen, The Statistical Movement in Early Victorian Britain: The Foundations of Empirical Social Research (Sussex and New York, 1975); ed., H.Woolf 'The Conference in Quantification', Isis, 52 (1961), 133-352.
2. For example, see figures and sources quoted by R.J.Barnet, R.E.Müller Global Reach, The Power of Multinational Corporations (London, 1975).
3. It is notable that Econometrica, the journal of the 'International Society for the Advancement of Economic Theory in its relation to Statistics and Mathematics' was initiated as recently as 1933. See also B.L. Welch, The Biometricians and the Development of Statistics: An Inaugural Lecture (Leeds, 1968), pp.16-23 on the general development of stochastic theory and empirical data; S.Pollard, 'Economic History - A Science of Society?', Past and Present, 30 (1965), 3-22.

violent conflicts within the ranks of this new intellectual caste,[1] it is still true that without these 'social scientists' the fragile systemic balance now operating on many levels would slide towards chaos.

During the last century profound cultural changes have been wrought through broader dissemination of these interpretive methods. It is no longer possible to argue a case in politics or governmental theory without a wealth of supporting data and the war of words has been complicated by a new war of statistics. Many sections of society have adopted crude, but nonetheless potent attitudes which depend on comparative analysis.[2] In this way enumeration has become the stuff of politics, and has permeated every aspect of our perception of human progress.

Given the central role of these contemporary methods, it is of paramount importance for historians to describe their origins and implications. This importance is underlined by the fact that awareness of the universal application and broad heritage of these techniques, is of comparatively recent origin.[3]

Although the collection of socio-economic data did not originate with them, seventeenth century intellectuals and officials raised its proficiency and application to an entirely new level.[4] Charles Davenant gave one of the first accounts of the antique origins of these techniques in his Discourse of the Use of Political Arithmetic,[5] but this was sadly deficient with regard to the earlier part of his own century. In reality

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1. For such 'ideological' conflict see R.Chashi 'The Study of Statistics in Japan: its Development, Present State and Future Task' Kyoto. Univ. Econ.Rev., 29 (1959), 40-77.
2. Random examples of this outlook are 'Poor vs. Rich: A New Global Conflict', Time, (22 December, 1975); D. Geddes 'Counting on children', article on Bulgarian women, The Times (29 December, 1975), p.5.
3. Cf. discussion of these applications in Clark, Conditions of Economic Progress, op.cit., pp.11-12.
4. Cf. Clark, Science, Social Welfare, op.cit., pp.120-133; idem, Guide to Commercial Statistics, op.cit., x-xvi; Cassedy, Demography, op.cit., pp.6-10.
5. Discourses on Publick Revenues, op.cit., pp.8, 18, 34.

a multitude of factors encouraged the development of such enumeration. For example, the important cultural role of Bacon, Hartlib, Robinson, Wood, Collins and others, in cultivating schemes for geographic natural history and economic planning, has already attracted lengthy comment. This literary movement reinforced trends which gave rise to the London Bills of Mortality,[1] an occupational census in Gloucestershire (1608),[2] Jacobean calculations of imports and exports,[3] an innovative (but short-lived) Council for 'Advancing and Regulating ... Trade' in 1650,[4] a notable set of early proposals for the 'Inrolling of Apprentices' (1607) and 'more Perfect Register of Baptizings, Marriages and Burialls' (?1614),[5] and a tithe-count of London in 1638.[6] By the end of the century outstanding progress had been made in governmental procedures for regulating trade, mainly through the pioneering influence of men like Worsley, Southwell, Locke, Davenant, King, Houghton, and Petty.[7] Unfortunately, this practical pro-

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1. Cf. Hull, Economic Works, ii, lxxx-xci; R.H.Kargon, 'John Graunt, Francis Bacon, and the Royal Society: The Reception of Statistics', J.Hist.Med., 18 (1963), 337-348; Webster, Instauration, pp.446-465, provides essential background to the earlier context.
2. Cf. A.J. and R.H.Tawney 'An Occupational Census of the Seventeenth Century' Econ.Hist.Rev., 5 (1934-5), 25-64.
3. Clark, Science, Social Welfare, op.cit., p.127; Supple, Commercial Crisis, op.cit., pp.257-267.
4. C.H.Firth, R.S.Rait, Acts and Ordinances of the Interregnum, 1642-1660 (London, 1911), ii, 404 - instructions 6-8, calling for statistical accounts of imports and exports, international exchange rates, customs and excise; Webster, Instauration, pp.459-465.
5. Magdalen College, Cambridge, Pepys MSS. 2870, pp.141-144, 'A Project grounded upon ye Statute of 5. Eliz[abeth] cap.5 for Inrolling of Apprentices, 24 Novemb. 1607'; ibid, pp.145-149, 'A Project written by Henry Martin, Gent, and dedicated to his Highness ye: Pr. of Wales, touching a more Perfect Register of Baptizings, Marriages and Burialls'.
6. Cf. T.C.Dale, The Inhabitants of London in 1638: Edited from MS. 272 in the Lambeth Palace Library (2 vols. 1931, Soc. of Genealogists), pp.iv-v.
7. Cf. C.M.Andrews, British Committees, Commissions, and Councils of Trade and Plantations, 1622-1675 (Baltimore, 1908); R.M.Lees 'Parliament and the Proposal for a Council of Trade, 1695-6', Eng.Hist.Rev., 54 (1939), 38-61, which established Davenant's central role in this development; E.A.O.Whiteman, 'The Census that Never Was: A Problem in Authorship and Dating' in ed., A.Whiteman, J.S.Bromley, P.G.M.Dixon, Statesmen, Scholars and Merchants: Essays in Eighteenth Century History (Presented to Dame Lucy Sutherland), pp.1-16, gives an excellent account of Petty's enquiries and the so-called 'Compton Census' of 1676. Petty also utilised these figures, cf. B.M. MSS. 38, Box I 'Religion', folder vi, i, 'An Estimat .. of Protestants, Papists [etc] ... 1686'. For Houghton's interest cf. Private Correspondence of Samuel Pepys, ed., J.R.Tanner (London, 1926) i, 39-45, 263-5. Southwell was an influential member of the Board of Commissioners who (1695-6) recommended the creation of the post of Inspector General of Imports and Exports. Cf. Clark, Guide to English Commercial Statistics, op.cit., pp.1-5. On Locke cf. Letwin, Scientific Economics, op.cit., pp.147-181.

gress lagged far behind the more advanced theoretical systems suggested by Petty. Nonetheless, although fragmentary and to some extent short-lived, contemporary achievements such as the 'Instructions for the Council of Trade' (1672),[1] and the essays of Graunt and Halley,[2] were remarkable.

This admixture of pressures and trends was a direct reflection of the increasingly complex demands made on central government. The interchange of cultural developments and bureaucratic problems - brilliantly capitalised on in the Down Survey - was also recognised by other European states and individuals. This led, for example, to a statistical survey of Hesse-Cassel (completed c.1590),[3] the Universitätsstatistik of Hermann Conring,[4] demands by Stevin for mathematised social science,[5] demographic analyses by the Huygens brothers,[6] de Witt's annuity calculations,[7] and Neumann's statistical observations.[8] However, it was in England that the most coherent body of practitioners and theorists developed, culminating in the great achievements of Gregory King at the end of the period. In exactly the same way as progress in seventeenth century physics can (somewhat

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1. Cf. Andrews, British Committees, op.cit., pp.107-108, 117-124, especially instructions 3, 6-10, 14.
2. For Halley's brilliant 'Estimate of the Degrees of ... Mortality of Mankind drawn from curious Tables of the Births and Funerals at the City of Breslow, with an Attempt to ascertain the Price of Annuities upon Lives', cf. Philosophical Transactions, cxcvi (January, 1693), 596-610; Ronan, Halley, op.cit., pp.133-136; H.Westergaard, Contributions to the History of Statistics (London, 1932) pp.32-37.
3. Cf. L.Zimmermann, Der Ökonomische Staat Landgraf Wilhelms IV, von Hessel (Marburg, 1933-4, 2 vols.); C.P.Clausen 'The Empire before 1618' in ed., H.R.Trevor-Roper, The Age of Expansion, Europe and the World 1559-1660 (London, 1968), p.132.
4. Lazarsfield, 'Notes on Quantification ...' op.cit., 286-292; Conring lived between 1601 and 1682.
5. Dijksterhuis, Simon Stevin, op.cit., pp.123-125.
6. Westergaard, Contributions, op.cit., pp.25-27.
7. Ibid, pp.27-28. For early English development of commercial annuities cf. R.W.Arithmeticall Questions (London 1613); J.Purser, Compound Interest and Annuities, (London, 1634).
8. Westergaard, Contributions, pp.32-33.

anachronistically) be measured by comparing William Gilbert with Isaac Newton, so, in the enumerative social sciences, Bacon, Browne[1] or Harriot[2] can be compared with Petty and King.

Formulated in simple terms, statistical enumeration is essential to the process of government because 'if knowledge is power, then ignorance is impotence'. However, it required a figure with Petty's unique experience to grasp the full meaning of this concept. Following Bacon's dictum, he realised that there was a great need for 'active' men of the world to write about 'speculative'[3] elements of economic, social and governmental behaviour:

> 'Hinderance of the advancement of learning hath beene because thought, theory, and practice, hath beene always divided in severall persons; because the wayes of learning are too tedious for them to be joyned. And whereas all writings ought to be descriptions of things, they are now onely of words, notions, opinions, theories - because the writers of books know little of things, and the practicall men have not language nor method enough to describe [them] by words'. 4

For Petty these writings were firmly rooted in the empirical procedures of Baconianism and the Down Survey, in his experience of Irish administration, and in a mathematico-deductive reasoning which was derived from continental scientific method:

> 'God send mee the use of things, and notions, whose foundations are sense [and] the superstructures [are] mathematicall reasoning; for want of which props so many Governments doe reel [and] stagger, and crush the honest subjects that live under them'. 5

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1. For Browne's calculation of the growth of world population before the Flood, in Pseudodoxia Epidemica (1646), cf. Greenwood, Medical Statistics, op.cit., pp.21-23; Sir T.Browne, Pseudodoxia, ed., G.Keynes, The Works of Sir Thomas Browne (Oxford, Sec.Ed., 1964) ii, 424-438.
2. For Harriot's estimate of world population cf. Brit.Mus. Addit. MSS. 6782, f.31.
3. Cf. prefatory quotation by Austen at the beginning of this chapter.
4. Lansdowne, Petty Papers, ii, 7-8.
5. Ibid, i, 111.

This particular fusion of experiential and intellectual influences originated with Petty and led him to make discerning proposals for governmental reform, with the same confident precision that illuminated his educational prospectus in 1648.[1] Moreover, his empiricism sets him apart from Hobbes[2] and his method of mathematical 'ratiocination' can be differentiated from Graunt's technique of applied 'Shop-Arithmetick'.[3]

Between 1660 and 1686, Petty outlined a central government department which would collect statistical information on every aspect of British economic and social life. Naturally, he also suggested that he be given ultimate control over this institution, under the title of 'Register Generall of [the] People, Plantation, and Trade of England'.[4] Although Petty's concept remained the same, he altered its detailed terminology to meet changing circumstances. Thus, in 1660-1661, it was tailored to overcome the problems of the Irish land settlement and was known as 'The Registry of Lands, Commodities and Inhabitants [of Ireland]'.[5] In 1682 this reappeared as 'A Comission for the Survey of the Lands, People, Trade and Revenues in Ireland',[6] and, in 1686, his own role was expanded to that of:

> 'Accomptant generall for all the Lands and People in the King's dominions.
> Valuator generall for all lands, howses, and Tythes in Ireland.
> Regulator of coynes in Ireland, as also Licences for selling ale, wine and spirit.

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1. For a corroborative opinion see A.F.Chalk 'Natural Law and the Rise of Economic Individualism in England', J.Polit.Econ., 59 (1951), 332-347, especially 342-343.
2. Compare this with R.Peters, Hobbes (London, second ed., 1967), especially pp.178-224.
3. For this phrase cf. Hull, Economic Works, ii, 323. For further discussion see section 'b' below.
4. Lansdowne, Petty Papers, i, 171-172; see also ibid, i, 172-181 for similar proposals.
5. Ibid, i, 77-90; for the background to the settlement, cf. D.Ogg, England in the Reign of Charles II (London, sec. ed., single vol., reprint, 1967), 389-400, passim.
6. Lansdowne, Petty Papers, i, 98-102.

> Commissioner for the Union of the English and Irish people and Interests, as also for Relieving the wronged Irish Catholiques, and Settling the well - affected English in what they hold by the Acts of Settlement and Explanation'. 1

Although totally impractical within the immediate political and bureaucratic context, these plans were invested with Petty's proven ability to organise and direct cadastral surveys, geographical natural histories, and demographic enumeration. His proposals were therefore comprehensive, clear, and minutely detailed.

Petty's description of the 'Irish Land Registry[2] achieved a remarkable level of sophistication. As an extension of the Down Survey (and other enumerative exercises of 1653-1659) its prime function was to establish an empirical basis for land tenure, equitable taxation, government reform (local, judicial, penal, administrational), centralised planning and economic improvement. Although couched in verbal terms, practical implementation depended on mathematical procedures derived from commercial arithmetic and surveying. Leaving aside (for the moment) the theoretical problems of evaluating different plots of land and the intrinsic relationship between rent, labour and market demand, it seems that this was the most comprehensive and practicable scheme for social enumeration to appear in seventeenth century literature. When this plan is allied to Petty's 'Statistics for a Registry'[3] and his 'Comission for the Survey of Lands, People, Trade [etc]' his unique understanding of the potential of such techniques becomes apparent.[4] Char-

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1. Ibid, i, 258.
2. Ibid, i, 77-90.
3. Ibid, i, 91-96.
4. Cf. Ogg, Charles II, op.cit., p.735 '[Petty had] an extremely broad and enlightened view of the good that might come from the collection and co-ordination of information and its proper use by the State - these were the qualities which made [him] distinctive in an age of remarkable men'.

acteristically this understanding did not end with mere exegesis of theoretical procedures: as an archetypal Baconian Petty whole-heartedly believed that these 'luciferous' experiments should, and indeed would, have 'fructiferous' results.

> 'And hee [the Surveyor Generall] is hereby Directed and Impowred to digest all the Said Accompts into One Body or Systeme to bee called the State Survey of that our Kingdome; and make such alphabets, Indixes, Tables, Schem[e]s and Abstracts of all the severall matters therein contenyned, with such Inferences and Applications as will reasonably arise out of the said premisses, and as tend to the better and more easy Administration of our Government, and the Advantageous management of our Revenue'. 1

At this point it should be noted that Petty's attitude to 'Political Arithmetic' was corroborated by his idea of 'Political Anatomy'. Utilising the well-established analogy between the human body[2] and the body-politic, Petty extended this comparison in a famous statement which prefaced The Political Anatomy of Ireland:

> 'Sir Francis Bacon, in his Advancement of Learning hath made a judicious Parallel in many particulars, between the Arts of preserving both in Health and Strength: And it is as reasonable, that as Anatomy is the best foundation of one, so also of the other; and that to practice upon the Politick, without knowing the Symmetry, Fabrick and Proportion of it, is as casual as the practice of Old-women and Empyricks.
>
> Now, because Anatomy is not only necessary in Physicians, but laudable in every Philosophical person whatsoever; I therefore, who profess no Politicks, have, for my curiosity, at large attempted the first Essay of Political Anatomy'. 3

This pronouncement directly links Petty's medical training with his later development of social science. As in his former profession,

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1. Lansdowne, Petty Papers, i, 100.
2. See C.Hill, 'William Harvey and the Idea of Monarchy' Past and Present, 27 (1964), 54-56; Hobbes, Works, op.cit., iii (Leviathan), ix, 'Introduction', for the famous passage 'a State ... is but an Artificial Man [etc.]'.
3. Hull, Economic Writings, i, 129; cf. Chapter 2, pp.224-6 above.

Petty's attitude to governmental regulation depended on detailed investigation ('curious and minute dissection'[1] joined with the natural history of disease), and a minimal amount of state intervention in socio-economic affairs (severely limited use of empirically-tested therapies). In his view there was therefore a direct parallel between the wise statesman and sagacious doctor:

> 'We must consider in general, that as wiser Physicians tamper not excessively with their Patients, rather observing and complying with the motions of nature, then contradicting it with vehement Administrations of their own; so in Politicks and Oconomicks the same must be used ...' 2

Above any <u>a priori</u> theory, or absolute premise, Petty placed an overriding emphasis on establishing exactly what the 'motions of nature' were, whether in medicine, economics or education. Only when the basic natural phenomena had been isolated, described and quantified, using a variety of specialised techniques, was it wise to speculate about natural and social laws, or which remedial policy should be applied to improve the existing situation. It is arguable, then, that if Petty's schemes had been implemented by the central government, they would have provided a vast array of statistical data on crucial problems such as longevity,[3] migration, religious affiliations, occupations, fertility, militia enrolments, illegitimate births, economic relationships, national wealth, agricultural productivity and the correlation between mortality, disease and weather patterns; brilliant though they were,

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1. Lansdowne, <u>Petty Papers</u>, ii, 173.
2. Hull, <u>Economic Writings</u>, i, 60 (<u>Treatise of Taxes</u>); see also Chalk, 'Rise of Economic Individualism' <u>op.cit.</u>, 343.
3. For Petty's table entitled 'A Bill for 10 Parishes' which was an exploratory questionnaire requiring statistical details from parish officials cf. Lansdowne, <u>Petty Papers</u>, i, 179-180; a more sophisticated version is the printed broadsheet at B.H. MSS. Volume 9, items 115 and 116. Cf. also Lazarsfield, 'Notes on the History of Quantification in Sociology' <u>op.cit.</u>, 277-280. Petty anticipated the act of 1695 for a complete parish enumeration; also Gregory King's Sample census paper was copied from Petty's earlier broadsheet. This is not acknowledged by Glass, <u>Population in History</u>, <u>op.cit.</u>, p.179.

Gregory King's 'Tables of Estimates'[1] would have been forestalled, contemporary British governments would have acquired a fundamental guide, and subsequent historians would have been spared much painstaking analysis and sophistry.

Unfortunately, as Petty realised to his cost, the science of the possible and the art of the practical were two entirely separate issues. It is an incontravertible fact that he failed to persuade the authorities to back his scheme, which remained unpublished and known only to a limited audience.[2] In 1674, Petty's hope that the Lord Lieutenant of Ireland would employ tax officials to collect information for his 'printed Directions about Numbering the People etc.,'[3] foundered on the reefs of suspicion, administrative incompetence, and cost. Despite Petty's vigorous attempts to gain state assistance for them, and cosmetic changes fitting them for each new situation, his plans failed to attract official support. These were some of the 'impossible things' for which he was castigated by Charles II.

This painful rejection forced Petty to take various actions which he hoped would mitigate the unpopularity of his scheme, or at least offset the restricted quantity of data available for his analysis. The first propitiations were again theoretical. Petty realised that, as with all 'projects', his motives were inevitably suspect and would suffer abusive

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1. For an excellent summary of the debate over demographic growth, and King's 'Table' of 1688, cf. Chambers, Population, Economy and Society, op.cit., especially pp.37-39, 108-109 and 114-115. Chambers says of John Rickmann, who 'almost single-handed ... undertook the organisation of the first census of the entire country': '[his] work was a great deal less controversial [than that of Malthus] but in some respects [was] vastly more useful'. The same could be said of Petty's proposals. Cf. also, Laslett, The Earliest Classics, op.cit., Introduction; Wolf, History of Science, op.cit., ii, 602-608; D.V.Glass, Numbering the People (Farnborough, 1973).
2. Some of Petty's ideas were, however, taken up in Pennsylvania. Cf. Cassedy, Demography in Early America, op.cit., pp.55-58, and Lansdowne, Petty Papers, ii, 111-119.
3. Robert Wood reported this set-back on 28 April, 1674, in a letter from Dublin, to Petty in London. Cf. B.H. MSS. Volume 6, iii, letter 52. A copy of these 'directions' is printed at Glass, Population in History, op.cit., p.179.

defamation.[1] He therefore provided a searching defence of the basic concept of statistical enumeration in his 'Cologuium between A.B.C. concerning a New Instrument of Government'.[2] As one of the most persuasive contemporary apologies for a new financial 'project', this polemical essay relied on an unusual feature. Petty reasoned: 'nor do I see of what great mischiefe even his failer [failure] may prove. For if no purchase, no pay'. In other words, the reward for providing this powerful new department would come from the net increase in royal revenue, calculated from a basis of the average return from the preceding seven years' tax farm.[3] Current royal income was guaranteed, there would be no ex gratia payment and no increase in administrational costs. All he required was legislation, which itself could be rescinded at any stage by an order-in-council. In 1683, despite the corruption of court officials and the gangrenous condition of the tax farm,[4] Petty nearly succeeded in obtaining royal support. Unfortunately, his scheme was displaced by Sir James Shaen (an old rival) who, upon the promise of a substantial increase in the King's revenue, secured a new lease for the existing arrangements. Charles II, master and victim of short-term expediency, can again be recognised ex pede Herculem.[5]

Another aspect of Petty's theoretical defence was his radical plan for a new constitutional structure. As an unsuccessful, but experienced courtier, he was fully aware of the strength of existing political and social forces. Moreover his scheme was designed to increase the hegemony of central government at the expense of other vested or sectional interests, placing an overwhelming instrument in the hands of the execut-

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1. For a lucid account of this phenomenon, and the pamphleteers' response cf. Letwin, Scientific Economics, op.cit., pp.79-98.
2. Lansdowne, Petty Papers, i, 103-111, undated but possibly c.1685.
3. Ibid, i, 102, 108.
4. Ibid, i, 76-77.
5. For the King's characteristic prevarication and procrastination cf. Ogg, Charles II, op.cit., pp.148-149, 539-540, 750; for the detailed background to Petty's proposals to the government, and his sacrifice of power for principle cf. Strauss, Sir William Petty, pp.120-145.

ive. Petty hoped to reduce the inevitable reaction of groups whose power was threatened by introducing new elements into the constitutional framework. These institutions would provide a system of popular checks and balances to oppose the enhanced power of government. Once again, details of the proposals were radically altered in response to successive changes in the immediate political content. At different stages he described a number of statutory councils and representative bodies,[1] a more coherently organised electoral system for the Commons[2] (based on wider enfranchisement), a strengthened House of Lords,[3] and outlined some revolutionary views on the relationship between legislative, executive and monarchical elements of the constitution.[4] Even if they had received wide publicity these proposals, despite their rationale, could have satisfied no-one and might well have prompted extremely hostile reactions. Small wonder, then, that Petty reported to Southwell: 'I am represented (as the Duke of Ormond told mee this day) by some to be a Conjuror, by others to bee notionall and fancy-full neer up to madness, and also a fanatick'.[5] He also bemoaned the lack of response from those in authority, echoing the bitter disappointment of 1648:

> 'I do not reckon all my right and reasoning to bee worth a straw, till I can get some powerfull person to consider it, I compose curious peeces in Musick and play them accurately; but all this while my hearers are as deafe as haddocks, nor will their eares (I feare) ever be opened with just application, till Wee run a Spit into them made of some convenient Metall'. 6

Nonetheless, he defiantly continued his ratiocination upon problems of government, economics and society, because this provided an anodyne

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1. Lansdowne, Petty Papers, i, 5-7 'The King and his Four Councills'; ibid, 11-13 'Of Plantation, Manufacture, Trade, Religion and Applotment'.
2. Ibid, 7-8 'Of the House of Commons'; ibid, 13-16 'Of Uniting England and Ireland by a Common Parliament' and 'An Expedient in Order to an Union of England, Ireland and Scotland'.
3. Ibid, 8-11 'Of a Grand House of Peeres'.
4. Ibid, 9-10, 16-21.
5. Lansdowne, P.S.C., pp.103-104, letter dated 16 September, 1682.
6. Ibid, p.91, dated 20 August, 1681.

against the wounds inflicted by private business and public vexations:

> 'You know my virtue and vanity lyes in prateing of Numbers, Weight and Measure; not sticking to talk even of the proporcons of Kinglomes and States ... [but] I had rather live upon Herb pottage all the dules of my Life ... than not to studdy truth and those Cyuiteries whereby the world stands and which are the causes why nes nolunt mali administrari'. 1

Given that this analytical process could not operate without a minimum of empirical evidence, Petty remarked in The Political Anatomy of Ireland that:

> ' 'Tis true, that curious Dissections cannot be made without variety of proper Instruments, whereas I have had only a commin Knife and a Clout, instead of the many more helps which such a Work requires: However, my rude approaches being enough to find whereabout the Liver and Spleen, and Lungs lye, tho' not to discern the Lymphatic Vessels, the Plexus [and] Choriodus ... yet not knowing, that even what I have here readily done was ... thought useful by others, I have ventur'd to begin a new work, which, when Corrected and Enlarged by better Hands and Helps ... will Tend to the Peace and Plenty of my Country ... ' 2

It is important to know what type of information was available to him, so that the nature of this 'commin ... Clout' can be established.

Sir William was a compulsive collector of statistical and enumerative data. For example he gathered material on 'K. Charles his Revenue for 10 yeares from 1625 to 1635',[3] on the military list of 1629,[4] on the revenues of various countries (Holland c.1662, France c.1673 and Ireland c.1683),[5] on royal debts (c.1671),[6] on the Hearth Tax (c.1674),[7] on custom's duties (c.1676),[8] on Anglo-French trade (c.1667-69),[9] on Irish revenues (c.1670,

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1. Ibid, pp.51-52, dated 19 March, 1673.
2. Hull, Economic Works, i, 149-150.
3. B.M. MSS. 30, Box A, Folder 4, item v. Petty probably garnered the following material from his own work in Ireland and from civil servants like Wood, Pepys and Southwell.
4. Ibid, item vi.
5. Ibid, items vii, viii; ibid, folder 6, item vii.
6. Ibid, folder 4, item x.
7. Ibid, item xii.
8. Ibid, item xiii.
9. Ibid, folder 5, item vi.

1685),[1] and on commissioned officers in Ireland (c.1686).[2] He also hoarded information on the size and state of the Royal Navy (c.1674-5),[3] the social and educational characteristics of students at Trinity College Dublin (c.1660-1681),[4] the numbers and status of M.P.s,[5] the size, working population and productivity of his colony in Kerry,[6] and the revenues accruing from the Poll Tax of 1666.[7] In addition he owned an incomplete copy of the Irish Census (c.1659),[8] and occasionally received unsolicited information from colleagues and friends like John Aubrey:

> 'Sr, I unexpectedly gott last Sunday night of a parish-Clarke, all the generall Bills from 1645, till next St. Thomas Day ... [and] on Sunday next I will wayte on you wth the Bills'. 9

Despite this growing repository of information, Petty's sources were severely restricted. Much of the material was fragmentary, suppositional or imprecise. None of it had been gathered as part of a coherent, systematic programme, and it was therefore more a by-product of other administrative procedures than an end in itself. This, as Petty realised, was no substitute for the information than an 'Accomptant Generall's' office would provide, and he was at a great disadvantage in comparison with King, who was later able to use more accurate data resulting from fresh taxation. Naturally, Petty was aware that any statement or calculation based on the material at his disposal was certain to be inaccurate. This did not

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1. Ibid, folder 6, items i, vii, viii.
2. Ibid, item ix.
3. B.H. MSS, 36, Box G, items 11-17.
4. B.H. MSS. 37, Box H, item 14, folder entitled 'Analysis of Students at Trinity College'.
5. B.H. MSS. 34, Box E, item 17 'The State of the House of Peers and Howrse of Commons ... with their Elections, Numbers and Wealth, 1685'.
6. B.H. MSS. 35, Box F, items 45-47.
7. B.H. MSS. 30, Box A, folder 4, item i; item ii is an account of the 1678 Poll tax.
8. B.H. MSS. 41, Box L. Printed in Pender, Census of Ireland, op.cit., Introduction, especially viii-ix. It is uncertain whether Petty was responsible for this census and, if not, when the copy came into his hands, since he was absent from Ireland during much of 1659.
9. B.H. MSS. Volume 6, ii, letter 99, dated 13 December, 1682.

necessarily invalidate his own, or other people's analytical methods, nor the proposals for administrative action which emerged as a direct consequence of such analysis:

> 'The Method I take ... is not very usual; for instead of using only comparative and superlative Words, and intellectual Arguments, I have taken the course (as a Specimen of the Political Arithmetick I have long aimed at) to express my self in Terms of Number, Weight, or Measure; to use only Arguments of Sense, and to consider only such Causes, as have visible Foundations in Nature; ... Now [these] observations ... upon which I bottom the ensuing Discourses, are either true, or not apparently false, and which if they are not already true, certain and evident, yet may be made so by the Sovereign Power, ... and if ... false, not so false as to destroy the Argument they are brought for; but at worst are sufficient as Suppositions to shew the way to that Knowledge I aim at ... Nor would it misbecome Authority it self, to clear the Truth of those Matters which private Endeavours cannot reach to'. 1

It has already been noted that 'Authority' was both unable and unwilling to shoulder this responsibility.

Petty's brilliant scheme therefore remained a private vision hidden among his manuscripts, known only to colleagues like Southwell, Pett, Williamson, Pepys, Wood and Aubrey, and rejected by a succession of worldly politicians and hard-pressed kings. Thus, apart from the Down Survey, these conceptual skills were not tested or expressed in an absolute form. This differentiates him from contemporaries like Ray, Boyle or Newton, in that they enunciated systems or scientific laws which were consistent and concrete. Yet to criticise Petty on the basis of a rigid (and misplaced) demand for actuality, is to judge him by criteria which are not applied to theorists such as Locke, Bentham, Mill or Marx. Moreover, other natural philosophers could isolate and investigate

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1. Hull, Economic Works, i, 244-245 (Political Arithmetick).

phenomena under controlled conditions, whereas socio-economic experiments depended on the vagaries of political control. Inflexible criteria and hostile judgments seem even more inappropriate when Petty's determined and repeated attempts to create appropriate governmental machinery, are taken into account. In the same way as Graunt's meticulous (but constricted) interpretation of mortality figures is validated by later statistical refinements, so Petty's broader viewpoint is validated by current reliance on advanced methods of enumeration.

On the basis of historical and modern evidence, Petty and Graunt should be viewed not as competitors, but as co-workers. Just as he controlled the Down Survey, 'contriving the way' rather than involving himself in detailed field work, so Petty sought to develop a data-gathering system which could guide governmental decisions. Within this context it was essential to employ the skills of shop-arithmeticians like Graunt and surveyors like Symner and Osborne.[1] By investigating a new problematic nexus these mathematical techniques would themselves have developed space. Such development was an exact analogue of the medical progress which could be expected from clinical teaching hospitals. Implementation of Petty's ideas might therefore have encouraged the evolution of two institutions capable of fuelling dynamic progress in their respective fields. Without them Graunt's method and others such as nosological history,[2] were forced to rely on commercial serendipity or the fortuitous interest of individuals like Halley and Sydenham.

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1. Webster, Instauration, p.440; see above, p. 129.
2. M.Greenwood, Epidemics and Crowd-Diseases, An Introduction to the Study of Epidemiology, (London, 1935), pp.46-49, discusses the problems underlying such a history: 'it seems that a vital or medical statistical system, codifying experience, is a necessary prerequisite of epidemiological research'. This conclusion would endorse Petty's plan for clinical teaching hospitals, which collected empirical evidence on disease and allied that with quantitative demographic research.

Before turning to the published expression of Petty's method, and comparing this with Graunt's Observations [on] the Bills of Mortality, it is necessary to give examples of his suggested application of enumerated data. One of the most lucid and succinct was concerned with controlling the number of clerics, lawyers and doctors. Petty regarded these classes with the gravest suspicion, believing them to be indolent, monopolistic and supernumerary.[1] This dislike prompted him to suggest central regulation of the professions, based on quantified research into their function and effectiveness. In the case of medicine he said:

> 'As for Physicians, it is not hard by the help of the observations ... lately made upon the Bills of Mortality, to know how many are sick in London by the number of them that dye, and by the proportions of the City to finde out the same of the Countrey; and by both, by the advice of the learned Colledge of that Faculty to calculate how many Physicians were requisite for the Whole Nation; and consequently, how many Students in that Art to permit and encourage; and lastly, having calculated these numbers, to adopt[a]te a proportion of Chyrurgeons, Apothecaries, and Nurses to them, and so by the whole to cut off and extinguish that infinite swarm of vain pretenders unto, and abusers of that God-like faculty ...' [2]

Further examples of Petty's inductive approach to complex social problems were his suggested reorganisation of London's suburbs[3] and his fervent belief in the value of sophisticated manipulation of the Irish economy, which would naturally result from the government's enumerative research:

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1. Petty wanted to expand the priesthood's role of recording parish affairs such as oaths, births, deaths, marriages, alcoholic licences, visiting the sick etc.; he gave a detailed list of fees for each function. Cf. Lansdowne, Petty Papers, i, 141-143. For the growth of the Professions cf. L.Stone 'Social Mobility in England 1500-1700' Past and Present, 33 (1966), 16-55, especially 19, 27.
2. Hull, Economic Works, i, 27 (Treatise of Taxes); Sharp 'The Royal College of Physicians ...' op.cit., 108-109, 120-126; Webster, Instauration, pp.250-264, 322, passim (Chapter 4).
3. See N.G.Brett-James, Growth of Stuart London, op.cit. pp.316-324 for a full treatment of this subject, and Lansdowne, Petty Papers, i, 25-42.

> '8: Knowing the fertility and Capacity of our Land, Wee can tell whether it hath not produced its utmost through the labours of the people. Wee can see whether plenty makes they lazey, and remeddy it. In briefe wee can find the best wayes and motives to make as many hands as possible to work, and that to the best Advantage we can adjust the number of Merchants to our Manufacturers, Maryners to the Merchants, Carpenters to the rate at which wee find Improvements to bee made, Trades of Ornament to the proprietors of the said Superfluityes etc. ...' 1

Petty's response to the problem of timber supply in post-Restoration England also warrants attention. It has already been noted that a major concern of the Discourse [of] Duplicate Proportion was the provision of rough estimative procedures for calculating the stress in beams, thereby obviating excessive use of structural members in ships and buildings. Another of Petty's interests was his belief in the need for scientific control of national timber reserves.

Although Petty has been accused of indiscriminate deforestation in Kerry, this charge is without foundation. It is true that the iron works used large quantities of wood for making charcoal, but these were replaced (as far as possible) by selective felling, replanting and coppicing.[2] Petty was fully aware of the increasing shortage of specialised wood products, particularly of 'knee-timber' for shipping, not only because the Naval Commissioners had negotiated with him in 1671 for a substantial consignment of Kerry oak,[3] but also because he was privately concerned with the financial and strategic implications of such a shortage:

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1. Ibid, i, 90; cf. also ibid, 85-89.
2. Thus Petty wrote to Waller, 2 August 1673, at B.H. MSS. Volume 19, p. 172 'Tell Crookshank that I am providing Men to plant hopes at Ballinboy ...'. The main reason for savage deforestation was, according to Petty, the illegal and rapacious 'cutting, felling [and] carrying away' of timber by the local Irish. Cf. Ibid, p.153, letter to Greatrex, 18 February, 1673, appointing Mr. John Orson to 'oversee [the] Woods'. See also Sharp 'Timber, Science, Economic Reform' op.cit., passim; Webster, Instauration, pp.480-483; B.H. MSS. Volume 19, pp.304-306, Petty's instructions to Crookshank 17 October, 1674, over timber; Petty Papers, ii, 125.
3. See his letter to the Commissioners, 25 September, 1671, at B.H. MSS. Volume 6, ii, letter 15. In a letter to Waller, 14 July, 1674, he said 'I heare nothing fro[m] Kerry ... I wish that at all adventures I had 20 or 30 tuns of Iron sent hither, with some Knee-Timber'.

> ' ... though this letter be long enough allreadye, yet it comes in my mind to cause as much Tymber-trees to bee planted on all my lands within 15 miles of Dublin, as they will beare if it can bee done for 3 half pence or 2[d] per Tree, and yt ye Tennants can be brought to preserve them, I would have you attempt it and comit ye care of it to fitt persons; for my opinion is yt a Tree of 2[d] will, in 50 yeares, be worth £20 for ye want of Tymber will be then and there very great ...' 1

In 1636, following a longstanding English debate over the condition of timber reserves, Petty devised a scheme that drew upon previous suggestions and linked these with his own demand for economic surveys.[2] At some point in 1685 he had received a copy of a document entitled 'An Act for the future increase of timber'.[3] He subjected this plan, which called for partial enclosure of the royal forests and subsequent husbandry of their standing timber, to minute scrutiny. Then, in a series of detailed counter-proposals, he developed his own programme. As a precaution he probably sought external criticism of these nascent ideas and he certainly pointed out their flaws himself.[4] The final unpublished result was another excellent example of his capacity for detailed, practical planning.[5]

The title of Petty's legislative proposal was 'An Act for the Perpetuall Supply of Timber and hemp both for his Majestyes Navy and other Shipping of this Kingdom'. Noting the need for stronger maritime forces, Britain's declining stocks of naval timber, the dangers of blockade and the inferiority of foreign supplies, this act called for the enclosure of

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1. B.H. MSS. Volume 19, p.337, letter to Crookshank, 16 February, 1675.
2. Cf. Lansdowne, Petty Papers, ii, 126-127, for Petty's incomplete ideas on forestry c.1672-3, and ibid, 127-129, for early version of his later plan.
3. B.H. MSS. 36, Box G, item 34. This document contains a large number of Petty's ms. corrections and deletions.
4. Cf. Lansdowne, Petty Papers, ii, 129-131, 'Inclosing Commons', and 126, where Lansdowne shows that he misunderstood Petty's intentions in this detailed cross-examination. Other preliminary drafts are B.H. MSS. 36, Box G, items 29-32.
5. Ibid, item 36.

all royal forests and parks. One half of this property was to be disbursed as payment against traditional rights of forestage, collecting and grazing. From the residue would come 240,000 acres 'most fit for the bearing of Timber and hemp', which would be divided into 80 equal parts and planted in rotation to give a continuous supply of timber. Detailed provisions were outlined to ensure that the woodland was well-maintained, and that both single arboriculture (essential for naval purposes) and blanket silviculture, would be practised. Similar procedures for the cultivation of flax and hemp would also be introduced. The ultimate rewards of this system were numerous. Apart from securing a guaranteed supply of naval products, the costly process of transportation could be minimised if new woodlands were planted near the sea, or close to a navigable waterway. The crown would avoid problems such as poor quality, cost inflation due to unforeseen crises, and the corruption of government officials; it would also gain the full benefits of forward planning. Although some advantages would not operate for an initial fifty years, the intermediate problem of timber shortage would be solved by deforestation of royal lands. This could confidently take place in the knowledge that future supplies were assured.

To implement this plan Petty asked the crown to initiate parliamentary legislation and charter a company with twenty wealthy and responsible stockholders. These men would lease the 240,000 acres, underwrite the initial costs of the project and commence rental payments within three years. The company would soon become liable for the provision of naval supplies at rates determined by the future (average) cost of staple products such as wheat. Given the historical mistrust of enclosure and royal abuse of forest law, the crown was also required to empower three commissioners to act as managers of the company and its associated land bank.[1]

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1. For other projected land banks cf. J.K.Horsefield, British Monetary Experiments 1650-1710 (London, 1960), pp.156-217, and especially 93, 106, on Petty.

These officials would immediately initiate a comprehensive survey of the royal chases, parks and forests, take depositions from all interested parties over traditional claims and rights of commonage, and provide an accurate account of existing timber stocks. This data would then be reduced to a standard format and made into 'books and Mapps ... to be returned to the Office/his Majesty's Surveyor Generall'. Final details of the scheme are provided in another document which lists those people whom Petty regarded as appropriate stockholders.[1] Among others, they included George Savile (Marquis of Halifax), the Lord Chancellor, the Lord Treasurer, Lord Ranelagh, Sir Christopher Wren, Sir Peter Pett, Samuel Pepys, Sir Anthony Deane, Sir James Hayes, Sir Robert Southwell and Petty.

Once again, his desideratum was unrealised. This was not surprising given the political climate of 1636 and continuing suspicion of his motives. Yet, despite complex problems inherent to the question of forest law and land tenure, there were no intrinsic grounds why execution of Petty's plan should fail. The systematic predetermination of those difficulties[2] and his scheme for enumerative research (when linked with clear legislation and contractual agreement), seemed to him the most obvious way to solve this perplexing economic and strategic situation. Even today it appears rational and well-founded.

Petty's failure to win government support for comprehensive socio-economic investigation and administrative reform is understandable in the light of contemporary events. The vagaries of politics, bureaucratic limitations, ingrained corruption, widespread conservatism, problems of cost, grandiosity of vision and his own suspect career all contributed

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1. B.M. MSS. 36, Box G, item 33; the list named 22 people altogether.
2. Cf. Lansdowne, Petty Papers, ii, 129-131, especially 'More particular Objections'. An earlier, less sophisticated scheme (c.1664/5) also foundered, but appeared valuable to the anonymous author T[homas] H[ale]. An Account of several New Inventions and Improvements (London, 1691), pp. xvii-xix; see also Keynes, Bibliography, pp.36-37 for this book.

to this failure. Yet many of his proposals appear, retrospectively, as practicable and thorough. Petty's realisation of the need for enumerative social and economic science was outstanding, though it was deeply influenced by reformist ideas of the commonwealth period.[1] Above all, he understood that rational government was only possible when scientific techniques provided a factual groundwork for governmental decisions.

Few contemporaries could comprehend Petty's attitudes and even fewer sympathised with them. Robert Wood accurately described the situation when, noting the reception of Petty's Discourse, he said 'they are more apt to censure than understand'. To those who did, Petty seemed a figure of outstanding intellect and vision. Wood, Graunt, Pepys, Southwell and Aubrey[2] shared this opinion, which was most clearly expressed by Evelyn:

> 'nor is his Excellency lesse in Counsil, and prudent matters of State: etc: but is so extraordinary nice in scifting, and examining all possible contingences, that he adventured at nothing, which is not Demonstration: There were not in the whole world his equal for a superintendent of Manufacturs, and improvement of Trade; or for to govern a Plantation; If I were a Prince, I should make him my second Counselor at least: There is nothing difficult to him ...' 3

While Petty's deductions about England's economic strength, or population, were certainly not solid 'Demonstrations', the rest of Evelyn's comment seems well founded.

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1. Notably Hartlib's further Discoverie of the ... Publick Addresse for Accomodations, op.cit., passim; see D.V.Glass, The Development of Population Statistics (1973, Gregg International Press), for the course of subsequent progress.
2. Wood to Petty, Appendix III, vi, 2, dated March 30, 1675. Aubrey was particularly effusive, cf. B.M. MSS. Volume 6, ii, letter 21, 17 July, 1675, 'could such a monke, such an object as I am, thinke that Sir W.P. who has so great concerns of his owne, so great thoughts for the Advancement of Learning: so great thoughts for the propping up of a Governm't thinke upon J.A.:? And since it is so, how can I expresse my thankfullnesse enough?' In a different context, Newton expressed a high opinion his pertinacity, cf. Newton's Correspondence, op.cit., i, 333-4.
3. Keynes, Bibliography, p.94.

(b) Political Algebra and Geometrical Justice

If the real world did not allow him to put his ideas to the test, it could not stop Petty from exercising his right to private 'ratiocination'. This process was derived from the geometric, algebraic and deductive natural philosophy that flourished in Paris during 1645:

> 'For my part I believe 1000 Inferences might be made out of those premises by a prolific Genious, for ye know that the 15 books of Euclid Eliments, were spun out of a few, plain and easy Axioms, and wee made a late Instance of Wonderfull Conclusions drawn out of the Bills of Mortality, which no man meddled withall in 70 years before the Author undertook it; and no man since hath either confuted or added any more unto, those conclusions'. 1

The basis for Petty's 'inferences' was that mass of statistical information which he compulsively stored away. It is his treatment of this data that differentiates him from Graunt or Halley and warrants both criticism and praise.

Graunt's profound and unprecedented study, Naturall and Political Observations [on] the Bills of Mortality,[2] was clearly the product of painstaking and lengthy analysis. This private research was, however, part of the broader reform movement which centred on Hartlib and was particularly sensitive to social and economic problems.[3] It has already been noted that in 1649 Graunt was entrusting his family's health to Petty,

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1. Lansdowne, Petty Papers, i, 105.
2. The fifth edition, printed in Hull, Economic Works, ii, 314-435, was published in 1676 and is utilised here. In addition to those already quoted, further sources on Graunt's work are: J.H.Cassedy 'Medicine and the Rise of Statistics' in ed., A.G.Debus Medicine in Seventeenth Century England, [Essays] in Honor of C.D.O'Malley, (California, London, 1974), pp.223-312; S.Matsukawa 'The 300th Anniversary of J.Graunt' Observations (1662)' Hitotsubashi J.Economics, 3 (1962), 49-60; D.V. Glass 'John Graunt and his Natural and Political Observations' Notes, Recs.Roy.Soc., 19 (1964), 63-100; see also the authoritative edition of Graunt's work by J.Willcox (Baltimore, 1939), pp.iii-xiii, and Hull, Economic Writings, i, xxxix-liv, lxxv-lxxix.
3. Webster, Instauration, pp.444-446.

who by then was an outstanding young doctor. Their relationship, obviously based on satisfactory medication, began to flourish as the older man gave Petty valuable assistance with his career. Although Graunt was not intimately involved with Hartlib's group (compared with Boyle or Worsley), he was certainly known to the great reformer, who noted in 1652:

> 'One King of the North of Ireland was brought unto me by Mr. Grant to give me special thanks for the publishing of the Natural History of Ireland ... He is very well acquainted with Colonel Hil, Petty, [and] Worsley'. 1

Before emigrating to Ireland Petty must, on occasion, have mulled over common intellectual concerns with his client, friend and patron. Given their relationship these discussions certainly covered medical matters and probably ranged over London's administration and population, since Graunt was an important figure in local government and the militia.[2] Another subject may well have been the implementation of economic, cadastral and topographical natural history, since Petty had a vested interest in this field by 1651. Graunt's experience may also have prompted discussion about military, political and business affairs. Particularly frequent meetings occurred while Petty lectured at Gresham College during the university vacations of 1650, 1651 and 1652.[3] Once in Ireland, his contact with old colleagues became intermittent. However, immediately on his return to the capital, he renewed previous friendships and joined Graunt in buying a property in the City of London. Released from the burdens of government and possessing broad experience of enumeration,

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1. Sheffield University, MS. Ephemerides 1652, HE/HE1 to HE/HE2.
2. A scrupulous account of his life is in Glass 'Graunt' op.cit., 63-69 and footnotes 1-52.
3. This is substantiated by references in Petty's fragmentary medical diaries for these years. Cf. B.H. MSS. 3, item 6, especially pp.13, 15, 24, 31. Petty's delivery of at least one of Graunt's children and his treatment of the young family's ailments is highly significant in this context.

informed interest in political theory and fresh enthusiasm for natural philosophy, Petty was a most stimulating companion for his business partner. John Graunt also had a remarkably keen intellect[1] which, while not as tumultuously fecund as Petty's, was notable for its incisive application. Their close relationship between 1659 and 1662 therefore provided a fertile environment in which to reaffirm and develop earlier interests.

Despite minimal evidence about their friendship between 1660 and 1662, it is still reasonable to assume that Petty and Graunt discussed subjects of mutual concern in the light of their experience and of current events. There is, therefore, little cause to doubt Aubrey's first statement that Graunt:

> 'Wrote Observations on the Bills of Mortality very ingeniosely; but I beleeve, and partly know that he had his hint from his intimate and familiar friend Sir William Petty ... and he intended, had he lived, to have writt more on the subject. He writt also some Observations on the advance of excise, not printed ... ' 2

The precision of this comment has often been overlooked. In no way did Aubrey claim that Petty wrote Graunt's work.[3] Nor did he diminish Graunt's intellectual stature in comparison with his more august friend. On the contrary, he sensitively struck the right note in reporting that Petty gave Graunt 'a hint'. Expanding on this, it can be argued that in 1660, having encouraged Graunt with verbal suggestions or one of his

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1. A.Wood described him as 'the most ingenious Person (considering his Education and Employment) that his time has produced'. Wood Athenae Oxonionses, (London, 1813) i, c.711-712.
2. Bodleian Lib. MS. Aubrey 6, f.97.
3. Cf. discussion of the date of Aubrey's comment in Glass 'Graunt' op.cit 99-100, footnote 125. Aubrey's later account does not invalidate this earlier one: it merely reflected gossip which was re-inforced after publication of Petty's Dublin Bills (1683) by Mark Pardoe. He was an enthusiastic supporter of Petty and, as Pett's letter at B.M. MSS. Vol.6, iii, letter 102, 11 July, 1685 shows, acted as agent for Petty's publishing. Petty referred to Pardoe as 'my Brother Beast', and Pardoe probably inserted on the title page of Dublin Bills, 'By the Observator on the Lond Bills ...' without Petty's foreknowledge or permission. Cf. also, Hull, Economic Writing,ii, 479-480; Lansdowne, P.S.C. pp.162, 166.

brief speculative 'lists', Petty then departed, spending much of 1661 in Ireland. Towards the end of the year he returned to find the tract in an advanced stage of preparation and executed with outstanding precision and originality. This highly creative work then stimulated further discussion of associated problems. Petty may have added certain literary embellishments to his friend's concentrated and workmanlike copy. The results of this close interchange were Graunt's Observations and Petty's Treatise of Taxes: two outstanding works that appeared one after the other in 1662. As much as there is a good case for suggesting that Petty gave tangential assistance to Graunt, so there is an equal case for supposing that Graunt helped Petty clarify his ideas on taxation. However, while there is no prima facie reason for thinking that either man was directly responsible for the other's precise thoughts, or for major contributions to his published work, it is also true that there is as yet no definitive evidence to settle this point. The only way that further light can be shed on the problem is by assessing the nature of each individual's ideas and their impact on subsequent commentators.

After a century of debate it has become clear that informed opinion among statisticians, economists and historians regards Graunt as the prime author of the Observations.[1] The ultimate basis for this belief is the identification of a common scientific and statistical methodology which runs through all his major arguments and conclusions. Up to fifteen separate 'regularities' (in the statistical sense) have been

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1. For this lengthy debate see Keynes, Bibliography, pp.75-77; Matsukawa, 'Origin ... of Political Arithmetic' op.cit., 61-65; Glass 'Graunt' op. cit., 78-89; Greenwood, Medical Statistics, op.cit., pp.36-39; Lansdowne Petty Papers, ii, 273-284; Hull, Economic Writings i, xxxix-liv.

identified.[1] Among these some of the most important are the high death rate in infancy (Chapter 2), the constant proportion between fatalities due to specific diseases and the total mortality (Chapter 2), the seasonal variation in mortality (Chapter 6) the ratio between births by sex and the total population by sex (Chapter 3) and the higher mortality of urban areas when compared with the country (Chapters 7 and 12). Another essential feature of this methodology is the cautious way in which unreliable evidence is scrutinised before calculation takes place. Classic examples of this trait are Graunt's analyses of the general character of the Bills and of the under-reporting of syphilis and the plague.[2] Where untested assumptions are unavoidable they are usually given explicit and realistic treatment. Although Graunt made a number of less felicitous assumptions (e.g. that the average family size was eight)[3] these were few in number and did not affect his more important conclusions.

The main body of Graunt's book therefore manifests a natural cohesion and scrupulous concern for the treatment of unreliable data. In 1662 the work gave unequivocal proof that demographic phenomena exhibited regularities in the same way as other natural phenomena. It also showed that these could be described statistically, just as topography and economic natural history could be quantified by geometric survey. Behind its approach lay a common intellectual denominator - that of the cautious shop-arithmetician who, at the end of the day, had to balance his books. It is precisely the intellectual quality one would expect. John Graunt, the patient, conscientious haberdasher from Birchin-Lane, used the materials at hand because they, like the facts of business,

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1. Matsukawa '300th Anniversary' op.cit., 56, n.27.
2. Hull, Economic Writings, ii, 346-348, 356, 363-366. He was also very cautious over baptismal records, ibid, 362.
3. Glass, 'Graunt' op.cit., 77; King's estimates of 5.0 for the number of persons per house for London, and 4.17 for England and Wales as a whole, are regarded as much more accurate.

constituted the immediate and available reality.

However, this picture reinforces speculation about some sections of Graunt's book. These queries, based on divergencies of literary and mathematical style, are mainly concerned with the letter to Moray (as President of the Royal Society), some portions of Chapter 7, the life table in Chapter 11 and the Conclusion.[1] The assumption behind these doubts is that in 1662 Petty 'improved' Graunt's work with some additions and stylistic modifications, thereby dressing up the text for publication. In an exercise designed to test this hypothesis Professor Willcox, following Hull's earlier example, excluded those passages which might have been inserted by Petty - assigning to him all 'eloquencies' of style, all unsupported conjectures and such numerical pronouncements as were scientifically unimportant. This reduced the text by almost one-eighth, but left behind a more coherent work.[2] Unfortunately, this hypothesis cannot be proven until fresh evidence appears. Nonetheless there are certain points which help support this interpretation and provide further illuminating possibilities.

To begin with there is an obvious change in the Conclusion's methodology and approach. This (like the section in Chapter 7) takes a much broader attitude towards enumerative data than the rest of the book. The tone is completely altered and instead of a cautious review of the previous argument this concluding section raises a host of new questions, applications and problems.[3] In a style more typical of Petty than Graunt, a list of unanswered queries is followed by incisive comments about the

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1. Successively in Hull, Economic Writings, ii, 321-5, 370-4, 386-7, 394-
2. Glass, 'Graunt', op.cit., 33-34. This also explains Petty's single, private claim to authorship of the 'Observations' in 1671. Dated 1660 in his 'Collection of Writings', Petty Papers, ii, 262, Petty never repeated or countenanced this claim in public.
3. See especially Hull, Economic Writings, ii, 394-5.

pointlessness of metallic transmutation, the pleasure derived from 'abstruse and unexpected inferences out of these poor despised Bills of Mortality', the reliance of 'Peace and Plenty' on uncorrupt government and the absolute necessity for broad socio-economic enumeration:

> '... the Foundation of this ... Policy is to understand the Land, and the hands of the Territory, to be governed according to all their intrinsick and accidental differences: as for example; It were good to know the Geometricall Content, Figure, and Situation of all the Lands of a Kingdom, especially according to its most natural, permanent, and conspicuous Bounds. It were good to know how much Hay an Acre of every sort of Meadow will bear; how many cattel the same weight of each sort of Hay will feed and fatten ... All which particulars I call the intrinsick value: for there is also another value meerly accidental, or extrinsick ...' 1

The subject, approach, even the language, are almost identical to Petty's 'Registry of Lands ... and Inhabitants (1660-61)'. In addition, many of the problems raised over the comparative value of land were subjected to brilliant analysis in the Treatise of Taxes a few months later. On these grounds the conclusion can reasonably be ascribed to Petty, or can be said to exhibit an overriding influence derived from Graunt's discussion with him.

The second aspect, and one which statisticians are usually reluctant to attribute to Petty, is the life table.[2] However, this reluctance is due to a false apprehension. If one accepts that portions of the treatise resulted from close collaboration, it must also be accepted that Graunt, as much as Petty, realised the significance of this particular exercise. Its salient features, apart from an emergent appreciation of the value of survivorship tables in general, are its approximative

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1. Ibid, 396; Hull, Economic Writings, i, xlix-l, corroborates this interpretation.
2. D.V.Glass 'Graunt's Life Table' J.Inst.Actuaries, 76, (1949), 60-64; idem 'Graunt' op.cit., 80-89; Greenwood, Medical Statistics, pp.15-16, 31-33.

method, its unjustified acceptance of a static population, and the more speculative nature of its content (viz. Chapter 11). These factors once again suggest the influence of Petty on his more meticulous and conservative colleague. Furthermore, as Professor Hull perceptively noted,[1] its most famous passage (quoted below) bears a strong resemblance to the 'Eleventh instance' of Petty's Discourse of Duplicate Proportion:

> '9. Whereas we have found, that of 100 quick Conceptions about 36 of them die before they be six years old, and that perhaps but one surviveth 76; we having seven De-cads betwen six and 76, we sought six mean proportional numbers between 64, the remainder, living at six years, and the one, which survives 76, and find that the numbers following are practically near enough to the truth; for men do not die in exact proportions, nor in Fractions, from whence arises this Table following'. 2

Now, this statement (i.e. 'six mean proportional numbers') and the ensuing mathematical treatment,[3] is far closer to Petty's normal style than to Graunt's; and although Petty later retained only limited and imperfect

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1. Hull, Economic Works, ii, 386, n.3. See also ibid, 391-2 for further cumulative tables.
2. Ibid, 386.
3. For Wood's criticism of the eleventh instance in Petty, Discourse, pp.82-88, see Appendix III, vi, 2, 3, below: Petty's reply is at ibid, 4, paragraph 6. Greenwood, Medical Statistics, op.cit., pp. 17-18 discusses this instance, but fails to connect it with the life table in Graunt's Observations. Glass in 'Graunt's Life Table' op.cit., and 'Graunt' op.cit., 88-89, does not make this link either. Instead he argues that Petty's failure to produce a self-checking life-table in Political Anatomy proves he could not have devised the table in Graunt's Observations. This argument (forgetting the vital similarities noted above) is unhistorical since Petty died before the publication of Political Anatomy and could not correct the mistake. In addition his careless attitude to transcription, acute astigmatic myopia and the variance of his amanuensi means that his correction of the manuscript(s) may have been cursory. Cf. Hull, Economic Writings, i, 122-4, 131, n.3. for details of publication and manuscripts.

knowledge of the Observations,[1] this was one specific subject that often reappeared in his essays during the 1670s and 1680s.

Petty's subsequent response to the problem took several characteristic forms. Firstly, there was his unyielding belief that however acute subsequent extrapolation might be, it could never claim to be as accurate as empirical data:

> '6. Without the knowledge of the true Number of People, as a Principle, the whole scope and use of the keeping Bills of Births and Burials is impaired; wherefore by laborious Conjectures and Calculations to deduce the number of People from the Births and Burials, may be Ingenious, but very preposterous'. [2]

This attitude would encourage the use of a more approximate, quasi-algebraic method, which Graunt's commercial arithmetic would be less likely to do. Therefore the characteristics of the life table in Graunt's Observations, of the eleventh instance in Petty's Discourse, of the calculations in his analysis of the Dublin Bills, and of his comment to Aubrey that 'I hope no man takes what I say'd about ... the living and dying of Men, for Mathematicall demonstracon'[3] appear consistent. All these instances were, in Petty's own words, 'ways of estimating', but they were no more than that. Because of this realisation, he returned time and again to the need for, and provision of, printed bills for the demographic enumeration of parishes.[4] These required

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1. Ibid, i, 45, n.2; ibid, ii, 517, n.1; ibid, 535, n.3; ibid, 536, n.1. are all examples of Petty's misquotations or misinterpretations of Graunt.
2. Ibid, ii, 485, Observations Upon Dublin Bills (1683).
3. Cf. Appendix III, vi, 8.
4. Lansdowne, Petty Papers, i, 179-180; Hull, Economic Writings, ii, 487-9; B.M. MSS. Volume 9, items 115, 116; Lansdowne, P.S.C. p.117. Halley (discounting his incorrect statement on the authorship of the Observations stressed this aspect: Philosophical Transactions, cxcvi (January, 1693) 596-7: 'But the Deduction from those Bills of Mortality [London 1662, Dublin 1683] seemed even to their Authors to be defective. First, In that the Number of the People was wanting. Secondly, that the Ages of the people dying was not to be had. Lastly that London and Dublin by reason of the great and casual Accession of Strangers who die therein, (as appeared in both, by the great Excess of the Funerals above the Births) rendred them incapable of being Standards for this purpose; which requires, if it were possible, that the People we treat of should not all be changed but die where they were born, without any Adventitious Increase from Abroad, or Decay by Migration elsewhere'. The Breslau Bills apparently met Halley's criteria.

information on age groups, sex distribution, fertility, occupation and family size.

Petty was therefore aware of the initial problems attending any life-table based on unreliable data. Hence he took an ambivalent, but interlocking view of its value. On the one hand it could be a useful estimative tool, from which highly stimulating 'inferences' could be drawn. This derived from his continental training in algebra and deductive science. On the other hand, as Petty's repeated call for a complete census indicates, and as an identical plea in the conclusion to Graunt's Observations may also suggest,[1] these 'inferences' were only approximate. They might or might not reveal universal mathematical ratios or regularities (i.e. 'geometrical justice'). Their only hope of certainty depended on the scale and accuracy of the primary figures and the only guarantee of accuracy was meticulous demographic enumeration. However, in conjunction with this attitude, Petty also grasped the essential point about a life table:

> '5. The numbers of people that are of every yeare old from one to 100, and the number of them that dye at every such yeares age, do shew to how many yeares value the life of any person of any age is equivalent, and consequently makes a Par between the value of Estates for life and for yeares'. 2

All this helps to explain why Edmond Halley (a better mathematician, possessing more accurate data) and not Graunt or Petty, was the first man to produce a viable life table.

Yet Halley's success does not detract from the scope of Graunt's achievement. Equally, the preceding discussion, and those that lack

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1. Hull, Economic Writings, ii, 396. 'It is no less necessary to know how many People be of each Sex, State, Age, Religion, Trade, Rank, or Degree etc ...'
2. Lansdowne, Petty Papers, i, 193 'Of Lands and Hands'.

appropriate manuscript evidence, cannot be accepted as definitive proof of Petty's contribution to the Observations. On this basis other arguments must also remain uncertain. For example it could be said that, over the life table, Petty's assistance diverted Graunt from a more precise development of this remarkable innovation. Nonetheless the mystery of Graunt's relationship with Petty is slowly being dispelled. In their separate ways both men helped to establish a new mode of thought by applying mathematics to social phenomena. Both were also aware that this new science sprang from the Baconian tradition. Therefore whether Petty or Graunt, or the two conjointly, penned certain parts of the Observations is, in one context, almost irrelevant. Whatever the precise balance of literary responsibility may have been, it is clear that they shared common assumptions and attitudes. In this light 'Graunt's' letter, dedicating the book to Sir Robert Moray, takes on a fresh and clear-cut significance:

> 'The Observations which I happened to make (for I designed them not) upon the Bills of Mortality, have fallen out to be both Political and Natural, some concerning Trade and Government, others concerning the Air, Countries, Seasons ... Health ... Longevity, and the proportions between the Sex and Ages of Mankind. All which (because Sir Francis Bacon reckons his Discourses of Life and Death to be Natural History; and because I understand your selves [the Royal Society] are also appointing means, how to measure the Degrees of Heat, Wetness and Windiness ...) I am humbly bold to think [this] Natural History also, and consequently ... I am obliged to cast ... this small Mite into your great Treasury of that kind'. [1]

Any divergence between the general attitude of Graunt and Petty is here so slight as to be indistinguishable. That this was conscious and deliberate seems likely, for the Treatise of Taxes made pointed reference to the Observations[2] and answered questions posed in the preceding volume. Ultimately, both authors were Baconians and, as such, shared

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1. Hull, Economic Writings, ii, 322 (Observations). Hull is prepared to concede this letter to Petty, ibid, i, lii.
2. Ibid, i, 27.

a common view of the purpose and value of natural philosophy.

Although Graunt published three further editions of the book before his death in 1674, he never attempted to write a second major work.[1] This was commensurate with his own personal problems.[2] On the other hand Petty, who survived his friend by thirteen years, published a number of polemical tracts which utilised their common techniques. He also wrote several major manuscript works which expanded on these established themes. Unfortunately, Petty's subsequent deliberations often exhibited a mathematical delinquency and lack of caution which undermined their value. This aspect of his later publications was readily criticised by Wood, King, Davenant and Arbuthnot. In his manuscript notes King questioned the estimative procedures contained in the eleventh instance of Petty's Discourse of Duplicate Proportion[3] by testing them against demographic information collected in the parish of Lichfield. This proved that Petty's proportional account of mortality ratios was completely mistaken.

More recent commentary has elaborated on Petty's failings. In a detailed analysis that was strangely unhistorical, yet statistically judicious, Major Greenwood showed that these duplicate ratios were 'wildly wrong'.[4] He then tackled Petty's demographic work in Verbum Sapienti, the Political Anatomy of Ireland, the Treatise of Ireland, the Essay [on] the Growth of the City of London, and Five Essays in Political Arithmetick. Each of these was found to rely on a host of untested assumptions, uncritical and unsubstantiated primary figures and inaccurate mathematical calculations. Greenwood concluded that 'Petty's statistical work ... is not of the calibre of Graunt's'. This equitable

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1. Cf. Keynes, Bibliography, pp.73-81.
2. Glass, 'Graunt' op.cit., 66-69.
3. Ed., Laslett, The Earliest Classics, op.cit., 'L.C.C.Burns J.' p.21.
4. Greenwood, Medical Statistics, op.cit., pp.17-27.

scrutiny was supported by Professor Glass[1] and extended in Letwin's[2] devastating treatment of Petty's mathematical carelessness and his cavalier treatment of sources. The case thus argued against large segments of Petty's published and unpublished tracts is formidable and often justified. In some ways, however, this argument omits or confuses certain historical factors that Petty's contemporaries rightly considered important.

We have already seen that Davenant and Arbuthnot believed that despite its erroneous conclusions, Petty's work performed the valuable task of proselytism. By spreading the idea of quantification and enumeration his tracts excited further interest. Moreover he showed that national wealth and economic relationships could be isolated and quantified, helping later figures like King and Davenant grasp the potential of these techniques. King's lengthy notation of Political Arithmetick[3] provides strong evidence for this conclusion. Secondly, in defence of the calculations themselves, Petty's remark that 'I hope better [ways of estimating] are now found out'[4] indicates his own awareness of these faults and the value of stimulating further research. Thirdly, he explicitly stated that his results and methods were 'at worst ... sufficient as Suppositions to shew the way to that Knowledge I aim at'.[5]

Petty's mathematical technique relied on algebraic procedures which aimed to express unknown quantities in terms of combinatory products of the known, thereby making the unknown quantities known. The method's accuracy depended on careful manipulation of simple mathematical procedures. Its factual reliability, with regard to policy formulation,

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1. Glass, 'Graunt' op.cit., 37-38. For the following works cf. Keynes, Bibliography, pp.34-35, 64, 17-19, 29-30. Between 1683 and 1687 seven demographic essays by Petty were published or reprinted.
2. Letwin, Scientific Economics, op.cit., pp.131-138.
3. Id., Laslett, The Earliest Classics, op.cit., 'L.C.C.Burns J.' 181 et. seq.
4. Appendix III, vi, 8.
5. Hull, Economic Writings, i, 245 (Political Arithmetic).

was hostage to those primary figures which constituted the 'known quantity'. If these were imprecise or inaccurate the final extrapolation could be dangerously misleading. Therefore two essential requirements for success were caution and precise calculation. Petty, who admitted to Wood that 'polishing is not my way', was predominantly careless and incautious in his application of algebraic technique. A choice example of these tendencies, correctly featured by Letwin, was the third of his Five Essays in Political Arithmetick[1] (1687). Here Petty wished to prove that London's population was 696,000. One of three possible 'proofs' was to establish the number of houses, then multiply this by the average of inhabitants in each house, thus achieving a reasonably precise population total. To succeed, the process demanded cautious assessment of the available data and meticulous calculation. Instead, Petty conjured up an 'authentick Report' of the number of houses destroyed by the Fire, claimed that the burials from these 13,200 houses were 'anno 1666 to be to those of 1636 as 3 to 4', summarily combined the data and concluded that 86,000 was the number of residential properties in 1686. Letwin has itemised a large number of unwarranted assumptions behind these figures[2] - to which one can add the fact that within the space of two pages Petty produced 'amended' totals ranging from 92,400 to 115,000 houses. Finally, since it fitted his original supposition, he arrived at a total of 115,846 houses. He also 'averaged out' the family size, in a completely cavalier fashion, reaching a penultimate figure of 6⅓, which was rounded down to 6. Throughout the exercise Petty used words like 'infer', 'pitch upon', 'there might be' and phrases like 'unto which supposition, the common

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1. Located at ibid, ii, 533-536. This should be compared with Halley's cautious, systematic and brilliant mathematical approach. Another example was Petty's conclusion that the French could never match English or Dutch naval power. Cf. Hull, Economic Writings, i, 273-284. Later events proved him totally wrong, as Pepys realised. Cf. Pepys, Naval Minutes, ed., J.R.Tanner (Navy Rec. Soc., 1926) pp.312-3, 316.
2. Letwin, Scientific Economics, pp.132-134.

opinion of several Friends, doth concur with my own conjectures', to support an unsubstantiated and hypothetical premise. However, these frailties were so obvious that they inevitably stimulated less wayward minds to search out better methods and information in the hope that more reliable results could be achieved.

Unlike many subsequent commentators, Professor Hull fully appreciated this effect.[1] His comparison of Petty's algebraic technique with the arithmetical approach of Graunt was equally perceptive. Hull's account supports the view that Petty's deductive methods were sometimes less acute, and sometimes on a par with those of Descartes and Hobbes. More damaging, perhaps, was the reservation of Petty's own cautious arithmetical work for problems like the Down Survey and the accounts and debts of his colony in Kerry.[2] Nothing, it seems, arrested his attention and disposed it toward careful calculation so much as the chance of profit or loss. The most fitting comment on Petty's statistical foibles was again delivered by Charles Hull, 'in the ardour of argument he was more than once misled into fancying that his conclusions were accurate because their form was definite'.[3] What 'misled' Petty was a combination of personality, polemics, careless scrutiny of sources and a method which, by its very nature, multiplied initial mistakes.

Bearing in mind the mixed calculative quality of political arithmetic and political algebra, it is important to reaffirm that Petty produced outstanding examples of economic and social analysis. There is neither the need, nor the space here, for a comprehensive account of his investigations, and only a brief description of two particularly

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1. Hull, Economic Writings, i, lxv-lxviii.
2. Innumerable examples of this capacity for precise and highly detailed computation are in Petty's letter book, B.M. MSS. Volume 19.
3. Hull, Economic Writings, i, lxviii. However, as Petty pointed out, the same could be said of Descartes' work on optics, and even of Hobbes (in the same field). Cf. above, pp.39-47 and 60, paragraph 5.

notable products will be given.

The most obvious of these has already been alluded to: Petty's pilot attempts to show that every constituent of a country's economy, and many aspects of its society, were amenable to analysis and quantification. Developed from the Down Survey, Petty's Political Anatomy of Ireland[1] was the broadest enumeration of economic and topographical natural history before King's work of the 1680s and 1690s. Although he rarely stated his source, since it was often private and unpublished, Petty gave a uniquely detailed picture of Ireland's condition c.1671-2. Where positive figures were unavailable he made intuitive estimates. At this point his 'extraordinary' capacity for 'examining all contingences' (Evelyn) was often sensitively applied. Thus, when discussing the acreage utilised for existing equine stocks he noted:

> 'To which purpose, remember that there are 184 M. [thousand] Families, whose Houses have but one or no Chimney. Now I guess, that about ⅓ of this number keep a small Horse [which therefore amounts to] 61,000 for Tillage: and I suppose that the 16,000 Families have for the Couch and Saddle near 40 M. Horses. So as in Ireland there are about 100 M. Horses, whose Food requires 1.0 M. Acres of good Pasture, 50 M. Acres of Meadow, and the 1/6 of an Acre of Oat-Land viz. about 16,000 Acres. In all 166M. Acres: Or if the Horses be such as require little or no Hay and Oats, as the Horses of poor people do not, then as aforesaid 2 of 2⅔ Acres is allowed to each Horse'. 2

By incorporating an element which allowed for the poorest group of horse owners, Petty's awareness of 'contingences', led him to avoid underestimation of the acreage requirement. A similar process was applied to coinage, lands, taxes, agricultural productivity, population, class, racial distribution and many other aspects of Irish life. The result

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1. Located at ibid, 121-231.
2. Ibid, 175. For an exemplary account of the extraordinary range of economic concepts first enunciated by Petty cf. G. Routh, The Origin of Economic Ideas (London, 1975), pp.35-46. These included: the labour theory of value, surplus value, differential rent, the theory of interest, the distinction between price and value, the role of monopolies, velocity of circulation, the multiplier and national accounting etc.

was an exceptionally sophisticated portrait of Ireland's society and economy. This was expressed in numerical terms, making it useful in the context of government and politics. An important factor differentiating Political Anatomy, from some of Petty's more immediately polemical tracts was the less strident and more cautious mode of estimation. Here, at least, Petty was generally achieving a level which matched his theoretical justification:

> 'To conclude: where the price of any goods are compounded of many particulars, which are also themselves not simple, and where all and each do vary according to many circumstances not obvious to everyone, there I say the estimate bona fide made by those of greatest practice and experience must be made use of; but still we must stick to number, weight and measure, till our senses and instruments of applying them fayles us'. 1

Petty's second major achievement was embodied in his economic theory. A succession of economists and historians have agreed that his finest work occurred in the Treatise of Taxes. For example Hull, Marx, Johnson and Strauss have all highlighted this tract. Letwin expressed this common judgment succinctly when he noted that instead of being remembered simply as the father of political arithmetic, 'Petty deserves a higher, though different reputation, as an economic theorist of the first order, the best or equal to the best that existed before 1750'.[2] Of the Treatise of Taxes he maintained 'despite [the] many flaws ... its basic structure must stand as a work of surpassing originality. The quality of its analysis makes it an unmistakable masterpiece of early economic science'.[3] Such analysis included Petty's brilliant attempt to define

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1. B.M. MSS. 36, Box G, folder 1^, original ms. and typescript of short essay entitled 'How all persons and things may contribute proportionally to their Government and Defence'. The statement that some complexities were beyond calculation was contracted and inserted at the beginning of Political Arithmetic. Cf. Hull, Economic Works, i, 244.
2. Letwin, Scientific Economics, p.114.
3. Ibid, p.146.

objective criteria for equating the 'real' value (and hence 'natural' relationship) of different plots of land, money rent and commodities.[1] A select group of principles gave system and unity to the tract, of which the most important was that no tax, government regulation or penalty[2] should be imposed that would reduce the production of socially acceptable goods. These striking theoretical insights have been rehearsed with great clarity many times before and it would be redundant to repeat this process here. All that will be noted is that they were the product of Petty's scientific training, government experience, penetrating intuition and organisational genius. Moreover, they were directly linked to his greatest practical achievement, the Down Survey, in that they sought to establish theoretical laws underlying the problems of cadastral valuation and subsequent taxation.

Petty's work as a socio-economic theorist, planner and analyst, while not without blemish, achieved a level of perception and clarity that places him on a par with his most original colleagues.[3] It showed that social and economic behaviour, like natural phenomena, required analysis on empirico-mathematical lines and that only when investigated in this fashion, without the intrusion of moral or religious values, could objective criteria and rational planning emerge. Petty never fell into the trap of conflating such values with 'scientific' investigation, though he was guilty of imprecision, unwarranted assumption and over-enthusiastic argument. Nonetheless, these faults, when balanced against the scope of his achievement, shrink, like Graunt's, to their

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1. These famous sections of the Treatise are at Hull, Economic Writings, i, 42-45 and 89-91. For similar explanations see Letwin, Scientific Economics, pp.142-6; Webster, Instauration, pp.443, 453; Hull, Economic Writings, i, lxx-lxxiv; Johnson, Predecessors of Smith, op.cit.pp.102-5.
2. For his ideas on penalties and 'pecuniary mulcts' cf. Hull, Economic Writings, i. 67-73. Petty's views on taxation were brilliantly elaborated in Verbum Sapienti, (written 1666-7, printed 1691). Cf. Hull, Economic Writings, i, 99-120.
3. Ibid, i, lxvi 'The application of an appropriate method "not very usual" to a field of knowledge in which it was altogether new, justifies [Petty] in associating himself with the most eminent followers of the new philosophy, and even distinguishes him among his colleagues'.

true measure. Above all, Petty realised the profound truth that the statesman or political analyst (like a wise physician) had no chance of successfully treating society's problems unless empirical data was collected, and basic causal factors were then isolated and quantified,[1] without bias or premature evaluation. Nature had hidden laws, and so did society. However glorious, a seventeenth-century minister could no more force aggregated humanity to behave in an 'unnatural' way, than he could stop the world turning:

> 'For, my Lord, there is a Political Arithmetic, and a Geometrical Justice to be yet further cultivated in the World; the Errors and Defects whereof, neither Wit, Rhetoric, nor Interest can more than palliate, never cure. For, Falsity, Disproportion, and Inconsistence cannot be rectified by any sermocinations ... Nam Res nolunt male administrari'. [2]

(c) Aiming at Impossible Things

It is as difficult to judge Petty's share in the 'Scientific Revolution' as it is to assess the character of that 'Revolution'[3] itself. This problem is mainly caused by changing historiographical[4] awareness and the complexity of Petty's career and intellectual development. Just as in the seventeenth century, modern views about the origins and character of scientific method are themselves in a state of flux.[5] Furthermore, the variegations of natural philosophy during this period expose general interpretations to immediate criticism. If there is a

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1. Even when intuitive, Petty's conclusions could be unusually perceptive. Cf. Lazarsfield 'Quantification in Sociology' op.cit., 281, for Petty's anticipation of Dusenberry's later use of sociological factors to help explain the economics of saving, and his comments on the psychology of work.
2. Petty, Discourse, Sig. A. 10v - A. 11r.
3. Caution should be used when employing this term. Cf. A.McLean, Humanism and the Rise of Science in Tudor England (London, 1972); A.P.D.Wightman, Science in a Renaissance Society (London, 1972); Raven, English Naturalists, op.cit.; Webster, Instauration, pp.484-520.
4. For one brief summary of this change cf. Q.Skinner 'The Role of History' Cambridge Review (March, 1974) 102-104 (corrected reprint).
5. This is true even at the most abstruse mathematical level. Cf. J.M.Ryder 'Subjectivism - A Reply in Defence of Classical Actuarial Methods' (paper submitted to Institute of Actuaries, 24 November, 1975), which provides a short synopsis of the Bayesian-Popperian debate. See also M.J.Osler, 'John Locke and Changing Ideal of Scientific Knowledge' J.Hist.Ideas, 31 (1970), 3-16.

reasonable starting point from which to progress towards the assessment of one individual's role, it is, simply, that any assumption of general homogeneity, consistency or steady progress is almost certainly misplaced. It is increasingly clear that there can be no universal explanation for this remarkable efflorescence, and that each natural philosopher, scientific subject or institution could accommodate various attitudes that might now seem incommiscible.[1] This does not deny that certain debates, influences or figures were central to the progress of natural philosophy. Rather, it should serve as a caveat to any historian who tries to establish an orthodoxy against which all seventeenth century natural philosophers are tested. Such selective procedures often end in the exclusion of those whose activity was 'scientific'[2] in the broadest sense, or who provide essential comparative information against which the achievements of more 'scientific' figures should be set.[3]

A common characteristic of English natural philosophers in the later seventeenth century was their polymathism. While it is obvious that each individual was keenly interested in particular pursuits and subjects, it is also clear that they shared a catholicity of interest. This was true of Halley, Wren, Newton, Boyle, Wallis, Hooke, Grew, Petty, Aubrey, Ray and most of their colleagues. There were manifold reasons for this eclecticism. For example, it was to some extent derived from a belief in the interrelationship of natural phenomena, which were seen as coterminous parts of the Divine Creation.[4] Equally, these men shared a growing

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1. For example cf. W.Pagel William Harvey's Biological Ideas (New York, 1967) especially pp.82-83, 89-124; Rattansi 'Newton and "the Pipes of Pan"' op.cit.; F.E.Manuel, A Portrait of Isaac Newton (Cambridge, Massachusetts, 1968).
2. Science is here defined as 'knowledge ascertained by observation and experiment, critically tested, systematised and brought under general principles'. See also K.T.Hoppen 'The Early Royal Society' Brit.J.Hist.Sci., 9 (1976), 1-24.
3. For further comments see my review of Hunter, Aubrey, op.cit., in Times Lit.Supp., 3, 863 (26 March, 1976), 351.
4. Exhaustive quotation here is unnecessary. However, see Lansdowne, Petty Papers, i, 118, 131, 136, 143-145; Raven, John Ray, op.cit., pp.452-478; M.B.Fisher, Robert Boyle, Devout Naturalist (Philadelphia, 1945); R.S. Westfall, Science and Religion in Seventeenth Century England (Yale, 1958) M.C.Jacob, 'Millenarianism and Science in the Late Seventeenth Century' J.Hist.Ideas, 37 (1976) 335-341.

certainty that nature operated according to hidden, but discoverable laws, which might function on mechanistic, mathematical, animistic, organic,[1] chemical,[2] or magical lines. Occasionally, these different explanatory modes coexisted in the mind of a single figure without any undue disturbance.[3] There was also a common, though not universal, assumption that the pursuit of fructiferous and luciferous knowledge, far from being mutually exclusive, was in fact mutually beneficial.

Thus, modern demarcations of 'science', 'technology', 'magic', 'metaphysics', 'mathematics', 'economics', and the rest, though not irrelevant, can be misleading if applied incautiously or without historical sensitivity. For while it is perfectly valid to delineate the internal chronology of a specific subject,[4] this must not be regarded as history in its broadest sense. To leave early modern science at this point is to leave it bereft of its full social, economic, intellectual and historical elements, a state which leads to inaccuracy and anachronism, since history is indivisible. Instead, reconstruction of scientific endeavour must take into account the framework which surrounds each scientific 'advance' or 'failure'. It must show the varying motivations, pressures, barriers, climates of opinion and personalities which provided the real content to such developments. Any other approach presupposes that the ground rules of scientific method have been identified and universally established. Also, it might encourage the fallacious opinion that it is the ultimate correctness of its deduction that makes a piece of research 'scientific'. If this was the case only the most recent work in a particular field could be termed scientific, and it would remain in that category

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1. See C.E.Raven's two illuminating essays: Synthetic Philosophy in the Seventeenth Century (Herbert Spencer Lecture, Oxford, 1945); idem, Organic Design: A Study of Scientific Thought from Ray to Paley (Friends of Dr. Williams's Library, 1953, Oxford).
2. Cf. A.G.Debus, 'Alchemy and the Historian of Science' Hist.Sci, 6 (1967), 128-138.
3. Hunter, Aubrey, op.cit., pp.93-147.
4. For example see the impressive R.S.Westfall, Force in Newton's Physics: the Science of Dynamics in the Seventeenth Century (London, New York, 1971).

until it was challenged, revised or extended by further investigation. The concept of a growing and varied corpus of scientific knowledge would give way to one which envisaged an accumulating pile of pre-scientific works which had been instantly displaced by the latest piece of science proper. This, too, would soon be pushed aside onto the rubbish heap of the pre-scientific. Even then, as in the case of iatro-chemistry, 'unscientific' attitudes, which played an important role in creating a fertile environment for subsequent progress, would be omitted completely.[1]

How, then, should Petty's work be assessed within the framework of his own extraordinary career, and the broader upheavals of the seventeenth century? As these remarks suggest, there is no simple interpretive mechanism that can answer every historical question raised by his activities and thoughts. Although the dominant theme of the present study, and, it is believed, of Petty's life, was his involvement with natural philosophy, this does not explain all the paradoxes and inconsistencies. For example, there is the problem of his repeated failure to establish the techniques of political arithmetic, anatomy and algebra. These brilliant methods of socio-economic analysis possessed enormous potential for the regulation and development of society. Yet they were ultimately rejected by almost every controlling group or individual in post-Restoration England. Petty's technological research also appeared to most of his contemporaries as hare-brained and a failure. Yet much of this research was based on methods that were essentially rational and scientific. Petty's own career was full of fortuitous events, like the accident which led him to the seminary at Caen, and the ease with which he survived the

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1. Even Ryder, 'Subjectivism' o.cit., 3, admits: 'Theories which cannot be falsified are unscientific (and relegated to metaphysics) but they are not valueless, since metaphysical theories are a fruitful source of subsequent scientific (i.e. Testable) theories'. See also, J.R.Jacob 'The Ideological Origins of Robert Boyle's Natural Philosophy' J.Europ.Stud., 2, (1971), 1-21.

watershed of the Restoration. Even his fundamental approach to scientific procedure was ambivalent: for example the deductive and linguistic techniques used by Petty when defending his Discourse were precisely those which, at other times, he strongly denounced. Finally, he often strayed from his normal positivism and empiricism towards fanciful and unrealistic ideas, like a scheme for the 'transplantation of all Irishmen into England and their replacement with English colonists.[1] However 'rational' this may have seemed to Petty, commonsense should have told him that it was both impossible and dangerous to suggest.

Nonetheless, a few salient features give unity and coherence to Petty's career. The first was a product of his remarkable personality and intellect. The combination of these two characteristics provided him with the capacity and insight to create, or take advantage of, those unique opportunities that came his way. At each succeeding stage they enabled him to climb from relative poverty towards financial success and intellectual prominence. Although his tumultuous involvement with worldly problems and virtuosic interests diminished his ability to concentrate on single issues, it also presented him with raw material for his outstanding social and economic analyses. When faced with the enormous challenge of surveying Ireland, Petty's energy and organisational skill led to his brilliant achievement in the Down Survey. This gave him training in governmental procedure and enlarged his understanding. Partly through this experience he came to regard society as a complex fluid structure, with concealed but indentifiable laws that were directly analogous to those which governed natural phenomena. This suggested that once these characteristics had been determined through the medium of statistical and numerical observation, axiomatic procedures for social improvement and control could be devised.

The second fundamental element in Petty's life was his early, and

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1. Lansdowne, Petty Papers, i, 46, 265-266.

prolonged, interest in seventeenth century science. His continental education introduced him to the most advanced ideas and systems of the day. Through this he became familiar with the work of many significant natural philosophers including Galen, Paracelsus, Harvey, Galileo, Descartes, Helmont, Gassendi, Suarez, Aristotle and Roberval. Equally important was his personal contact with Boll, Hobbes, Mersenne and the web of acquaintances and intellectual influences which surrounded these men. This experience left an indelible mark on Petty's outlook. Above all, he was thoroughly imbued with the empirical and social vision that dominated the work of Francis Bacon.

On his return to England he swiftly attached himself to Samuel Hartlib, the leading proponent of English Baconianism in its millenarian and puritanised form. Although Petty did not absorb or foster the pietistic elements of this Baconianism, he was deeply influenced by its utilitarian and technological content. Particularly important was his association with Hartlib's scheme for the Office of Address, with its accent on social enumeration. Realising, after several fruitless years, that his ambitions would not be satisfied by commercial development of new inventions, Petty pursued his career through the twin paths of academics and medicine. In this design he received significant help from Hartlib and his acquaintances. Oxford, London and state service in Ireland followed in quick succession. All the while Petty drew on those skills and contacts which his early training had so amply provided. It was this rich mixture of experience that sustained him through the eventful and productive years of his later life.

This interpretation identifies common factors behind the directional changes in Petty's career. Without assuming that his life and attitudes were entirely homogenous, it explains a large number of apparent inconsistencies. Thus, his later radicalism and stubborn support for social

amelioration are seen as a product of his early experience. Equally, his views on the correct role of the Royal Society and the need to apply scientific methods to regulate socio-economic affairs, were consciously inherited from pre-Restoration developments. If Petty's attempt to investigate social phenomena, using empirical and mathematical means, is regarded as an important dimension of later seventeenth century science, then it must be obvious that this development was firmly rooted in the work of Bacon and his puritan adherents. On the other hand, Petty's mathematical approach and his general involvement with natural philosophy were deeply indebted to his continental training. Even his knowledge of Bacon, geographical natural history and Harveian theory sprung from that experience.

We should not be surprised, therefore, when Petty's synthesis fails to accord with the monism of some recent interpretations of the 'Scientific Revolution'. Petty, like many other contemporaries, provides strong evidence for the pluralism of this movement. Thus, when he linked the most mundane technological research with religious and metaphysical considerations, this did not spring from confusion, but from a growing belief in the universal application of natural philosophy. His method of listing and defining questions was both a personal development of the scholastic *quaestio* and of the predications of Hobbes. Finally, his genius for planning, whether applied to the Down Survey, a training hospital, the country's economic regeneration or a restructured Royal Society, was the product of innate talent, the influence of Bacon and his puritan followers, historical opportunity, and Petty's own unyielding attitudes.

In the final analysis, Petty's various projects were completely overtaken by events after 1660. From his own point of view Charles II was right, Petty was 'ayming at impossible things'. Yet, in another

sense, Petty's unwillingness to compromise and his steadfast belief that his ideas were essential to science and human progress, not only helped save its institutional embodiment, but also added a new dimension to English natural philosophy. As Charles Raven has said, 'to ask the right questions is always an indication of real insight and often the most useful contribution to progress possible at the time'.[1] In his own fashion, Petty was outstandingly creative in asking 'the right questions' and equally creative in providing theoretical answers to them. It is ironical that, as a social and scientific prophet of the seventeenth century, Petty was rejected by the overwhelming mass of contemporary opinion. There is a corresponding irony in the fact that his methods were not irrational: on the contrary, those most central to his vision have been vindicated one after another, in medicine, in education, in modern scientific institutions, in technology, in economics and, above all, in the control of that most complex phenomenon, society.

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1. Raven, John, op.cit., p.477.

APPENDICES

APPENDIX I

THE LIFE OF A NATURAL PHILOSOPHER

i) Petty's Dialling Advertisement, c.1649

ii) Observations on the Royal Society, 1687.

iii) Advertisements for the Dublin Society, 1684.

(i) Petty's Dialling Advertisement, c.1649

This advertisement is in Petty's handwriting and located at Hartlib Papers, viii, 11, f.2r. It is representative of his attempts (c.1649) to gain support for his inventions, which in this case concern surveying and geodesy. The advertisement's date is suggested by its location, immediately following the affidavit (16 March, 1649) given by the Brewers' Company for Petty's distillation machines, at Hartlib Papers, viii, 11, f.1r. This affidavit is also in Petty's handwriting.

"Dialling"

here are to bee sold:

1. An Instrument whereby for all Spherical Triangles 2 sides being given the third may bee presently knowne without arithmeticall calculation.

2. An Instrument Whereby all Bodies may bee easily knowne by way of perspective that is even as they represent themselves to the eye.

3. An Instrument Whereby any building designed to bee made may bee easily represented by way of perspective according to the geometricall Ichonography and profit thereof.

4. An Instrument to measure all streight lines & distances geometrically at two Stations without Arithmeticall calculation.

What the Price of them will bee, we cannott yett tell. There will bee store of them made, If any desire to have them bee pleased to give Notice thereof. There are other & greater, Mechanicall Mysteries yett behind, but Monyes are Wanting to defray the Charges of them Wherefore wee must first begin with these smaller ones, The Author doth not as yett desire to bee knowne.

Kircherus his Booke entitled Natura machinis animata promiseth the Like.

(ii) Observations on the Royal Society, 1687

Even at the end of his life Petty was trying to put the Society's affairs onto an even keel. The programme outlined below shows that a few weeks before his death Petty was striving to achieve his aims: a well-organised, well-financed research institute, with systematic experimentation, and full educational facilities. Manuscript located at B.H. MSS. 37, Box H, folder 2, (ii), L.

Endorsed: "About ye Royall Society: 1° Decemb, 1687"

Things to bee done at ye Royall Society.

An accompt of Stock (certaine,
(hopefull
(other

The Solvent Members.

The Expense. (Crdinary
(Extraordinary

An Accompt of ye Library.

Of ye Museum and Repositaryes.
Of Supellex Philosophica.

The Journalls.

Letters Received.
Entryes of Letters sent abroad.
Reports) In archive.
Lectures)
Transactions printed.

An annuall course and systeme of Experim$\overline{ts}$ for 40° [weeks] and 160 days in ye yeare.
To Settle a Revenue of Income of 500 li p.an. for sallaryes and cost of Experiments.
A Councill of 7 for management, of ye some of 12 li p.an. Each.
To have 100 Solvent Members to Meet 40 weekes of ye yeare.
To have 20 Schollers to meet 160 times per year (4 times Each Week for 40 weekes)
Out of ye 24 Counsellors to chose 5 to Oversee ye Scholes at 5^{sh} Each time of their Coming.
The Scholers to pay 20 [sh] p.month.
Those who come in, 2 shill. [each] time.
The same at ye weekly meeting.

(iii) Advertisements for the Dublin Society, 1684

These should be compared with the preceding 'plan for the Royal Society'. They exemplify Petty's attitudes, not only to correct institutional procedures, but also to natural philosophy in general: enumeration, ordered experiment, utility, strict financial management, methodising of materials, the use of instruments. This version of the 'Advertisements' is printed at Birch, History, iv, 353-354.

1. That they chiefly apply themselves to the making of experiments, and prefer the same to the best discourses, letters, and books, they can make or read, even concerning experiments.
2. That they do not contemn and neglect common, trivial, and cheap experiments and observations; not contenting themselves without such, as may surprise and astonish the vulgar.
3. That they provide themselves with rules of number, weight, and measure; not only how to measure the plus and minus of the qualities and schemes of matter; but to provide themselves with scales and tables, whereby to measure and compute such qualities and schemes in their exact proportions.
4. That they divide and analyse complicate matters into their integral parts, and compute the proportions, which one part bears to another.
5. That they be ready with instruments and other apparatus to make such observations, as do rarely offer themselves, and do depend upon taking opportunities.
6. That they provide themselves with correspondents in several places, to make such observations as do depend upon the comparison of many experiments, and not upon single and solitary remarks.
7. That they be ready to entertain strangers and persons of quality with great and surprising experiments of wonder and ostentation.
8. That they carefully compute their ability to defray the charge of ordinary experiments, forty times per annum out of their weekly contributions, and to procure the assistance of benefactors for what shall be extraordinary, and not pester the Society with useless or troublesome members for the lucre of their pecuniary contribution.
9. That whoever makes experiments at the public charge, do first ask leave for the same.
10. That the secretary do neither write nor receive any letters on the public account of the Society, but what he communicateth to the Society.
11. That persons (though not of the Society) may be assisted by the Society, to make experiments at their charge upon leave granted.
12. That for want of experiments there shall be a review and rehearsal of experiments formerly made.
13. That the president at the present meeting shall order what experiments shall be tried at the following meeting, that accordingly a fit apparatus may be made for it".

APPENDIX II

SOCIETY'S IMPROVEMENT : EDUCATION, MEDICINE AND INVENTION

i) Q[estion] and Desiderata of [the] O[ffice] of Addresse.

ii) Observations on Petty's Advice ... to S.H. c.1648.

(i) 'Q[estion] and Desiderata of [the] Office] of Addresse'

Located at Sheffield University, Hartlib Papers, 1iii, 21, this short, anonymous document bears the Stamp of Petty's style, though it is probably not his holograph. In particular, paragraphs 1, 4 and 6 are typical of his viewpoint, and 1, which mentions the compilation entitled 'Vellus Aureum', links the manuscript directly to Petty's Advice (p.18).

Q[estion] and Desiderata of [the] O[ffice] of Addresse.

1. Wee could wish, that a work may bee compiled, whose title might justly bee VELLUS AUREUM Sive Facultatem Luciferarum Descriptio Magna, wherein all the knowne and practis'd wayes of getting a subsistance, and raising mens Fortunes might bee at large declared.

2. It might bee divided into 4 parts viz. The Historie of Manufactures, Mercature, Stipendiary Offices Publick and Private, and the Historie of Ministrations of all Sorts with an Appendix of other Miscellaneous wayes not reducible to any of the former heads.

3. The History of Ministrations (by which wee understand the Employment of Physitians, Lawyers, Atturnies, Proctors, and their Clarks, Secretaries, Scriveners etc: even to Serving-men) should treate of the best wayes of Acting in all those Severall Professions, with the demandable fees, or usuall gratuities given them for the same.

4. That all stipendiary offices (by which are meant all the great offices of the State the K^{s} Court, and Courts of the Indicature, Receipts of Customers, Commissioners for the Militia by Land or Sea, all keepers of Magasins, Storehouses, Commanders of Castles), should mention the duty of every such office, the Qualifications requisite unto them & all manner of Profits, Perquisites, and Priviledges usually enjoyed by the said officers as well directly as indirectly.

5. That of Mercature should explaine all the Mysteries of dealing, Ensuring, Adventuring etc: should tell what Commodities, Naturall and artificiall each Country doth produce, and into what other Countries they are vended and disposed, with all the busines of monies, their severall alloyes and weights, raising and falling of Exchange, The Customes of all Commodities in all places, what are prohibited to bee exported or imported into any Kingdoms, the differences of weights and Measures in severall countries, together with all Sleights (just or unjust) of all Dealers in generall and of each species of Trade in particular, whereby they adventure their owne, gaine and Interest.

6. The History of Manufactures, (which of all the rest formes, at least to me, the most pleasant and Philosophicall, the most honest & innocent, the most advantageous, as well to him that undertakes to write it, as the Publique) should consider all things, wherein the hand of Man hath anything to doe, plainly and at large, describing the whole Processe of manual operations, and Applications of one Naturall thing (which we call the Elements of Artificialls) to another, with the necessary Instruments and Machines, whereby every Manufacture is elaborated, and made to be what it is: For which worke in Particular bare word being not sufficient, all Instruments and tooles must bee pictured, and fitt colours added, when the Descriptions cannot bee made intelligible otherwise.

(ii) Observations on Petty's Advice ... to S.H. c.1648

This brief essay is located at Sheffield University, Hartlib Papers, liii, 36, 1. Its purpose is clearly indicated in the title and it makes a detailed appraisal of the costs, benefits and problems associated with each section of Petty's treatise. The clarity and business-like approach very much mirrors Petty's viewpoint. Although there is no definite evidence as to its author, Charles Webster has suggested that it may have been the work of William Rand (private note). For Rand cf. Webster, Instauration, pp.304-308.

> A Remonstrance of the feasability of the Designes described by W.P. in his Advices to Mr Samuel Hartlib, concerning the Advancement of Learning and Arts.

Vast Summes are indeed requisite to the atchievement and perfection of the Workes designed by WP. in his Advices concerning the Advancement of Learning, and not only vast Summes but answerable proportions of time and labour also. But to beginn, and (as hee himself expresseth it) to Set those Designes on floate, Neither the Summes, time nor labour necessary thereunto doe exceede mediocrity, there beeing only wanting unto them a propitious and wise Authority to make the other and more masculine parent of these conceptions.

1. As for the Office of Addresse, when it is once begun, when the world beeing sensible of its benefit, shall fly unto it for Accommodation, and Authority shall secure the first Labourers in it, from the disturbance of Intruders, In Reason and Experience the honest gaines arising from it, will sufficiently support and continue it. Wherefore the hire of two Convenient houses in London, entertainment for the Master of Addresses and wages for foure Registers for one yeare (all which will scarce exceede 500^{lb}) t'would perhaps bring the businesse to such a growth, as that afterwards Meanes and undertakers to Institute other Offices (according to the patterne of those in London) in all other great Townes of the Kingdome, would not long bee wanting.

As for Surveying the State of Learning, winnowing and sifting the same, it is a worke that may bee carried on in what proportion of dispatch the Undertaker thereof please, wherefore when there are Men found out able to appoint what Bookes shall bee collected, and to give directions for doing the same, a bare maintenance for 3 or 4 able Gatherers for a yeare or two, will procure a faire Essay and Experiment of that businesse likewise especially if any Mecenates shall before hand legally oblige themselves, to beare the Charges of publishing the said Collections and to gratifie the Collectors with the profits arising from them.

As for the Ergastula Literaria it is said that a Corporation lately ordained for the provision of the poore are going in hand to establish them, and that there are large donations allready made for that purpose: Wherefore for this Designe there needs but an Education of fit Educators, and the Invention of such proper Employments for little Children and Impotents of all Kindes, whereby each may earne his owne Subsistence without wasting the maine Stock of Endowments.

The very Instauration of the Gymnasium Mechanicum, as is set downe by W.P. will indeed bee a worke of 2 or 3 thousand pounds charge per annum. Wherefore if instead of that noble Foundation in the meane time the State would appoint the Tradesmen of London to make each of Them a Masterpiece in their respective Arts, allowing them 6. months time to prepare themselves thereunto, would conferre upon them of each profession that exceedeth the rest, the Title of beeing the Chiefe Workman or Parliament's Gunsmith [or] Cloth maker would give him leave to hang out some signe, which may notifie him to the world so to bee, allow him some small Priviledge or Immunity from Excise or such like taxe or Impost and in consideration thereof would oblige all those chief Workmen to grow together into one Society or Corporation for the Advancement of Arts and Manufactures and Manufactures, and to meete at certain times to consult thereupon, as also to enforme by word and deede such as should bee thought fit and able to couch and compile the History of the said Trades, I doe not as yet conceive what expence is requisite thereunto besides the hire of a Convenient place, whereat to meete and conferre as aforesaid.

For the Nosocomium Academicum, Wee are of the same opinion with W.P. that a Reformation and new moulding of one of the larger and richer of the old Hospitalls by the helpe and Industry of such Ministers, as hee hath described would satisfie this Designe.

For the History of Trades (in case the aforesaid Corporation of prime Artificers were setlet) I suppose that there might bee found Men to undertake and continue it if the charge of graving Figures, Transcribing, Painting and Translating the first yeares work were defrayed by Benefactors, and the profit by the said Bookes allowed the Compiler; the charge whereof would not exceed 800^{lb}.

Lastly the Collections of Reall Historicall and Experimentall Learning aforementioned, will bee in Effect an History of Nature, or would at least yeeld much of the Materialls requisite thereunto.

Therefore if Men cordially willing to undertake and able to mannage these Designes were in readinesse and the state ready to assist them with their Countenance and Authority lesse than 2000^{lb}. would begin them and make them strong enough to beare up themselves even till their arrivall to perfection.

APPENDIX III

THE DISCOURSE OF DUPLICATE PROPORTION

i) Memorandum on the Royal Society, 1674.

ii) Table of papers presented at Society meetings of 1674-1675.

iii) A table of the contents of the Discourse.

iv) The manuscript prologue to the Discourse.

v) An attack on the Discourse and Petty's reply.

vi) The Petty - Wood correspondence.

(i) Memorandum on the Royal Society, 1674

An untitled folio, in the hand of one of Petty's regular amanuensi, with authorial corrigenda throughout the text. It is not dated, but was almost certainly written between 7 and 15 October, 1674, cf. Birch, History, 3, 136-137.

Location: B.H. MSS. 37, Box H. 'Royal Society' Folder 2, ii, h.

Whereas his Ma^{ty} in his Princely wisdome, thought fitt to Institute a Society for the emprovement of Naturall Knowledge, as the firmest foundations of all other Arts and Sciences, relateing as well to Divines as to Civill and military Matters; and gave the Name of ROYALL unto the said Society, declareing him self the Patron and Founder thereof. By reason of w^{ch} his Maty's Institution and example, as also of the vigerous endeavours and cheerful contributions of many worthy Persons, It came to pass y^{t} severall other Soveraigne Princes, Dukes, Prelates, Peeres wth other Dignitaryes and Gentlemen of all sorts, thought fitt to inscribe them selves unto the said Society. So as the fame and reputation thereof hath since spread it self unto all parts of ye Knowne World, and great Numbers of Ingenious and Curious Persons even of all Nations, Religions and Interests, did indifferently covet their friendship and correspondence and did dedicate their Books and Labours unto them, Making them Arbitors of the Chief Disputes and Controversies hapening within ye Province of their Institution. But so it is that (by reason of the immature desires of some, to bee listed into the said Society, before they were sufficiently resolved or prepared to joyne effectually in the ever Lawdable Designe of Promoteing Naturall Knowledge) the Ordinary Contributions necessary for the makeing of Experiments for defraying ye Postage of forraigne Correspondance and for gratifying such Assistants as were necessary to the generall work, did very much faile in and from the last mencioned persons, and by their Example, others formerly well affected to, and well deserving of the Said Institution, did so slacken both their Labour and payments, That at length, scarce any Man, not contented to be thought singular, either paid his Subscriptions or brought in Experiments, or so much as attended the Meetings of the Society, to the great discouragem^{t} of those, who had already actually been, and others who intended to bee Benefactors to ye same, but most of all to the great disappointment of his Sacred Maty^{ty}, the dishonour of his Charter, and the Vilifying of ye other ensignes of Honour and authority by his Said Majesty granted to that Corporation.

Upon consideration whereof and the President and Councill of the said Society being weary of calling for the arrears due unto them, from such as have been most exemplarly backwards to pay them, and being not willing to press others (more forward to contribute their Labours and Monyes) meerly to pastime for those first aforementioned, Have resolved to select out of their whole Catalogue, such a part of their Numbers as are most willing to rebuild ye Society aforementioned not onely by paym^{t} of their respective arrears, but also by advanceing other Sumes, and most of all by their engagem^{t} Weekly to bring in some peece of ye History of Nature or Art, to review, methodize and emprove what of that kind hath beene already registered, to fitt up an Apparatus for Severall Illustrious experiments, and so as well by their own said Endeavours as by calling more strictly upon their Curators for the punctuall performance of their respective Undertakings to Restore ye said Society to its prestine Efficacy and Reputation.

And in order to ye premisses They have thought fitt, and do hereby desire That all Such Members of the Society as resolve not to pay their arreares, nor to make some reasonable composition for them, would forbeare comeing to the meetings of the said Society, and by not continuing their disrespects so discourage or disturb, there better disposed Members, who have engag'd as aforesaid: Further Intimateing unto all such as desire to quitt the Society, that their leave shall bee readily granted them according to ye Statutes, and Lastly that they shall hereafter become weary of admitting such, as shall not give better assurance of their affection to the true ends of his Mat^{s} Royall Institution, to ye Com'on good of Mankind therein and to ye honour of their Country who first engaged in that glorious Undertaking.

(ii) Table of papers presented at Society meetings 1674-1675:

These discourses resulted from the initiative to increase the frequency, and improve the quality of papers and experiments, which developed between August 1674 and February 1675. One of the leading instigators of this programme was Petty. For the following table the source of information about the delivery of lectures has been volume iii of T. Birch: History of the Royal Society. Before a full picture of the formative years of the Society can be given, it will be necessary to compile similar tables for 1663-1700 dealing with: frequency of meetings; presentation of work; attendance levels; fluctuating history of membership including new elections, expulsions or deaths; publication of works on natural philosophy by order of the Society, dedicated to the Society or to leading Fellows; and a detailed record of the financial state of the institution. Only when such exhaustive materials are represented in tabular form, will the fortunes and periodicities of the Society begin to emerge.

Discourse mentioned or printed in Birch, History,3.	Date of meeting and presentation of the discourse	Author of lecture or paper	Title of lecture or paper	Date when ordered to be printed	Date and nature of publication	Main proponents in ensuing discussion and experiment, as recorded in Birch
143	1674 12 November	John Wallis	A Discourse of Gravity and Gravitation	28 January 1675	1675 short pamphlet (36pp)	Hooke on elasticity
printed 144-153	19 November	Robert Boyle	'Experimental notes of the mechanical origin or production of fixedness as opposite to volatility'			
156-157	26 November	Sir William Petty	The Discourse ... Concerning the Use of Duplicate Proportion	10 Dec 1674	1674 small treatise (135 pp)	no immediate discussion. Experiments on elasticity proposed.
159	3 December	Robert Hooke	'a discourse concerning the construction and uses of his new quadrant'			Ward, Petty, Wren, Moore.

161	10 December	Nehemiah Grew	A Discourse ... Concerning the Nature, Causes, and Power of Mixture	21 January 1675	1675 Small treatise (120 pp) later reprinted in Anatomy of Plants 1682, pp 221-237	exhibition of experiments from the treatise
printed 162-174	17 December	John Ray	two discourses: 'on the seeds of plants' and 'on the specific differences of plants'.			
	1675					
174	7 January	No major discourse: a letter from Martin Lister dated: 'York, November 24, 1674'			Printed Philosophical Transactions, 25 Jan, 1675	Number cx. 221-226
175	14 January	Robert Hooke	'observations of the late lunar eclipse of January 1st'	14 January 1675	referred to in Philosophical Transactions 9 Feb. 1675	Number cxi, 22 237-238
175	14 January	Robert Boyle	'discourse of freezing' previously registerered 23 Nov, 1671			several experiments suggested
177	21 January	Daniel Coxe	'a lecture concerning the analysis of vegetables'			Hooke et.al., debating analysis of plant salts and elasticity.
179	28 January	Robert Hooke	A description of Heliscopes ...		1675, published separately as a small treatise (32 pp) and reprinted in 1679 as part of Lectiones Cutlerianae	

179-180	4 February	Edmund King	a discourse on animal anatomy			Hooke, Grew, Croune discussing points.
181	11 February	William Croone	a discourse on the musculature and mechanics of bird flight			Hooke, Petty, et.al., on modes of flight and its utility
printed 181-190	18 February	Thomas Henshaw	an account of observations in Denmark			Petty on comparison of tides in the Baltic and Mediterranean. Hooke on pocket watches.
192	25 February	Nehemiah Grew	a discourse on: The Anatomy of Trunks	21 October 1675	The Comparative Anatomy of Trunks 1675	Hooke on longitude
192	4 March	Isaac Vossius	two discourses: 'De apparentions in Luna Maculis' and 'De Speculo Archimedeo'			Hooke discussing lunar geography, Teneriffe's appearance and Archimedes' burning glasses
192	4 March	John Webster	Displaying of supposed witchcraft (committee of Pell, Petty, Miles)	1676	1677	
193	4 March	David Coxe	a discourse on the improvement of Cornwall by sea-sand		printed: Philosophical Transactions 10, Number cxiii 26 April 1675 293-296	

193	11 March	the author designated to give the lecture was absent. Thus an essay by Robert Boyle was read out	'a discourse formerly given in ... about shining flesh'			Hooke opening up question of general nature of light. Apparatus to be prepared for testing Newton's theories
194-195	18 March	Robert Hooke	a discourse 'concerning the nature and properties of light'		Hooke: Posthumous Works, R.Waller, 1705, pp. 186-190	
195	25 March	Nehemiah Grew	'A Discourse of the Diversities and Causes of Tastes chiefly in Plants'	25 March 1675	Anatomy of Plants, 1682, pp. 279-295	Hooke et.al., on the nature and utility of Grew's theories
196	1 April	'The Society did not sit'				
196-216	8 April	Sir Robert South-well	'A discourse concerning water'			
216-217	15 April	no major lecture; letters from Leibnitz on pocket watches, Beale on agricultural improvement, Vossius on Hooke's previous comments				Hooke defended his earlier observations on paraboli-cal glasses for burning
217-218	22 April	Robert Boyle	a 'Discourse concerning the mechanical production of Tastes'	22 April 1675	Printed in: Experiments Notes etc. about the Mechanical Origin or Production of divers particular Qualities, 1675, pp. 3-35	

218	29 April	John Evelyn	Part one of: Philosophical Discourse of Earth	17 June 1675	Printed in, and as an appendix to the third edition of Sylva, 1679	
219	6 May	no major lecture: various letters on air bladders in fish, on a water engine and on Scottish observations				
219	13 May	John Evelyn	Part two of: Philosophical Discourse of Earth			
220	20 May	Isaac Vossius	a translation read of part of his: De Motu Marium			general discussion
220	27 May	Three short papers: Lemery on salivation; Taylor on a sword fish; and Locke on poisonous fish in the Bahamas			Locke's paper printed in Philosophical Transactions, 10, Number cxiv, 24 May, 1675, 312	
221	3 June	Dr. Jackson	an account of the salt springs in Cheshire, (a previously registered paper)			discussion on the origins of springs and rivers; Sir James Long on Wiltshire and Petty on agricultural improvement
222	10 June	no major discourse. Oldenburg reports French work on origin of rivers			reviewed in Philosophical Transactions, 10 Number cxix, 22 November, 1675 447-450	general discussion. Hooke elaborates on Wren's weather clock
223	17 June	Nehemiah Grew	a 'discourse concerning the trunks of plants'		incorporated in: The Comparative Anatomy of Trunks, 1676	Petty & Hooke on the warping of wood. Grew and Henshaw on the motion of sap in trees

225-226	24 June	no major lecture. Hooke demonstrates his Heliosscope; reception of several types of earth from Plot in Oxfordshire; letter from Gregory on the motion of the earth; French information on pear-fruits			
227	1 July	no major lecture. Letters from Ray, Lister, Flamsteed, Malpighi			
228	8 July	no major lecture; Hooke's experiment on air resistance			
Summer Recess. 8 July to 28 October, 1675					
228	28 October	Nehemiah Grew	'a lecture concerning the nervous liquor ...'	28 October 1675	
229	4 November	Robert Hooke	Lecture on self regulating lamp		used as material for: Lampas: or Descriptions of some Mechanical Improvements of Lamps & Waterpoises... 1677
230-231	11 November	no major lecture: Hooke makes further observations on lamps. Various letters read out by Oldenburg			
231-232	18 November	no major lecture: letter from Papin & Huygens on the air pump; letters from Newton & Linus on light			these letters are printed in Philosophi-Transactions, 10 Number cxix, 443; Ibid Number cxxl, 500; Ibid, Number cxxi, 499

printed 232-241	25 November	Walter Needham	experiment on a dog's lymphatics: followed by a lecture on 'the serum of the blood'		
242	30 November	Anniversary election, no discourse			
246	2 December	no major lecture: letter about damps in mines from Francis Jessop of Broomhall in Sheffield; Hooke demonstrates two lamps and questions the nature of mine-damps		Jessop's letter is printed in: Philosophical Transactions, 10, no.cxvii, 26 September, 1675, 391-393	
printed 247-260	9 December	first part of manuscript sent by Newton on his theory of light and colours, read by Oldenburg		cf. also: Newton Correspondence, ed.,I.B. Cohen, 1, 363-392	active discussion of particular experiments
260-269	16 December	second section of manuscript by Newton on light, read by Oldenburg; Hooke disputed its originality, Petty comments.			trial of experiments
270-271	30 December	John Aubrey	Observations made in Wiltshire further Newton letter. Death of Linus noted.	partially incorporated in: The Natural History of Wiltshire, ed. J. Britton, 1847	general discussion of mineral exhibits

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Note: On 17 June, 1675 the Society ordered the printing of two works, which were not presented at its regular meetings. These were reported in Birch under the following titles:

(1) 'Francisci Willughbeii de Middleton Armigeri; quondam e Societate Regia, Ornithologia'

(2) 'Marcelli Malpighii Philosophii et Medici, e Societate Regia, Anatome Plantarum ...'

(iii) A table of the contents of the Discourse

This table illustrates the differences between the printed and manuscript versions of this treatise, and nature of its contents. A rough indication of the importance that the author attached to various subjects, and the preponderance of his own interests, can be gleaned from a comparison of the length of individual sections with the total length of the text, and with each other.

Section	Title and Function	In Manuscript only	In printed text only	In both	length: page number or foliation
1.	Order by Council of Royal Society, signed by Brouncker, P.R.S., for Discourse to be printed, dated 10 December, 1674		Yes		[one page]
2.	Title Page		Yes		[one page]
3.	Dedicatory Letter to 'William, Lord Duke of Newcastle'. 31 December, 1674		Yes		[21 pages] Sig. $A^{3}-a^{1}$
4.	Dedicatory Letter to 'William, Lord Viscount Brouncker, President of the Royal Society' 31 December, 1674		Yes		[4 pages] Sig $a^{2}-a^{3}$
5.	Errata		Yes		[1 page] Sig. a^{4}
6.	Part of manuscript prologue omitted from printed version at beginning of introduction. cf. Appendix 3, section iv.	Yes			ff. 1-2
7.	Introduction, and summary of the 'instances wherein Duplicate and Subduplicate proportion is of use in humane affairs'			Yes	pp. 1-20
8.	The first Instance applied to Shipping: velocities, resistance due to hullshape, relative cost of ships of differing sizes and speeds			Yes	pp.21-41

Section	Title and Function	In Manuscript only	In printed text only	In both	length: page number or foliation
9.	The second Instance: structural resilience and comparative strength: of timber 'scantlings', in ships, in model as opposed to full scale 'engines', in buildings, in animals, small or large, in casks of different sizes			Yes	pp.41-55
10.	The third Instance: In the comparative power of different oars and rowers			Yes	pp.55-60
11.	The fourth Instance: In the speed and carrying capacity of horses.			Yes	pp.61-63
12.	The fifth Instance: wind and water powered mills			Yes	pp.64-65
13.	The sixth Instance: explosive force of gunpowder, in guns of differing capacities			Yes	pp.65-70
14.	The seventh Instance: range of differing intensity			Yes	pp.70-73
15.	The eighth Instance: range smells of differing intensity			Yes	pp.74-76
16.	The ninth Instance: distance at which objects of different sizes and lights of differing intensity can be seen			Yes	pp.77-79
17.	The tenth Instance: comparative time of swing taken by pendulums of differing lengths			Yes	pp.80-82
18.	The eleventh Instance: 'in the life of Man, and its Duration'			Yes	pp.82-88
19.	The twelfth Instance: musical harmonies and progressions.			Yes	pp.88-90
20.	The thirteenth Instance: the comparative strength of fires and the expansive capacity or alcoholic value of different liquids			Yes	pp.91-96

Section	Title and Function	In Manuscript only	In printed text only	In both	length: page number or foliation
21.	The fourteenth Instance: Water pressure and flow in pumps, ship leakages and rivers of different magnitudes or speeds			Yes	pp.97-103
22.	The fifteenth Instance: air pressure 'In the Blast of Bellows' of different sizes			Yes	pp.104-105
23.	The sixteenth Instance: the price of several commodities: ship masts, ship timber, diamonds, of differing sizes			Yes	pp.106-110
24.	The seventeenth Instance: In the strength and necessary dimensions for reinforcement of mill-dams, sea banks and bulwarks of fortresses			Yes	pp.111-113
25.	The eighteenth Instance: 'In the compression of Yielding and Elastic Bodies as Wooll etc.'			Yes	pp.114-120
26. (i)	'An Appendix of Elasticity'			Yes	pp.121-135
(ii)	A section of this Appendix, missing in the manuscript version, has been inserted into the printed text, from [p.130] 'Lastly I might suppose' ... to [p.132] ... 'to all other principles of Generation'	Yes			pp.130-132
27.	Conclusion			Yes	pp.132-135

(iv) The manuscript prologue to the Discourse

This represents the original section of the treatise which Petty included when he delivered it to the Royal Society on 26 November, 1674. The manuscript version is in the large, clear hand of one of the author's regular amanuensi and authorial corrigenda occur throughout this copy. The complete text of the manuscript occupies thirty-nine folios, whilst the first section of the Prologue, omitted for obvious reasons from the printed work, is two folios in length. The manuscript copy of the treatise is located at B.H. MSS.40, Box K, 'Transcripts and MSS of Printed Books', Folder 9. Another copy of this prefatory section, possibly that removed from the version submitted to the printers (since its final section approximates more closely to the beginning of the published work), is given here and is located at B.H. MSS. Volumes 12, 32:

The Prologue:

The primitive Lustre and Light of this Society hath of late burnt dimm, 'Tis for the Honour of God (whose Immutable Laws Wee Study) Of the King (the Patron and ffounder of this Institution) of the Nation (whose ffame was emproved by our first Indeavours) and lastly of the Members themselves (who are Princes, Peeres, Prelates, Doctors of all Faculties, and Gentlemen of all Titles, Qualifications, Offices and Interests) that this Society should not wholly Sinke and quite vanish away.

Now to recover this lost Lustre, severall meanes have been used (some with more, some with less effect, but none with enough) and the remedy now under tryall, is to lay togeather, and blow upp some of the old Brands of that Pile, which once gave soe considerable a fflame hopeing when they have rekindled the fire, that then soe much fresh and fitt fuell may be laid on afterwards, as shall begett not onely a beautifull Blaze of Reputation in the world, But alsoe a steddy and wholesome heate, throughout all the Limbs and Bowells of Philosophy.

The Councell have taken mee out for one of these Brands; But alas! the little Coale, which was left on my Stick, has been battr'd away with many Violent bruises of heterogeneous Cares, and my whole bogg has for many years lain Sogging in the Cold and Wett of inconsistent thoughts, that you must Expect noe fflame from me, Nor but a Fume of Steam of some old Notions, which the Accumbent heat of the two worthy members who went next before me, has made to smoake upp a Little (scarce to burne) much less to warme, forment, and invigorate our languishing Undertakings.

But when I consider that the end of these Dawning Exersises, is not of a Sudden to Scorch men's understanding with Moon=Beames of Experiment and Demonstration, But rather by graduall repefactions, at length to come to the feircest reverberations of Naturall Difficulties; I hope by my Taliter = qualiter performances, to amimate the most desponding and Bashfull member of this Society to bring his ffaggott also to this new fire, from all which burning togeather, Wee may promise Ourselves an advantageous illumination of this Age, and of the whole world about us.

[continues as in printed work: 'Forasmuch as this Society ...]

(v) An attack on the Discourse and Petty's reply

The two letters printed here represent the most extensive contemporary criticism of Petty's treatise and his response. Two manuscript copies of the first are known to exist, at B.H. MSS.6, Section 3, Letter 76 and Royal Society MSS Early Letters, P.1, f.32. This manuscript is in the clear hand of a copyist. The second is in that of Henry Oldenburg. There are no significant differences between them and for this transcription the Bowood House copy was utilised. Another variant of this letter was published by Sir Peter Pett in his edition: The Genuine Remains of ... Dr. Thomas Barlow, Late Lord Bishop of Lincoln ... (London, 1693), pp.151-156, as the product of Barlow's pen. In this ascription Pett is now open to question since the copies at Bowood and the Royal Society are both signed with the initials 'L.M.' Pett's edition was also called into question over its general accuracy at the time of publication, and this letter may well be a specific example of this failing. Petty's reply to this attack is known to exist in at least two copies, at B.H., MSS 6, Section 3, Letter 61 and Royal Society MSS Early Letters, P 1, f 32. The Bowood House copy, which has been utilised for this transcription, is in the hand of an amanuensis with corrigenda by Petty. The Royal Society copy is, once again, the work of Oldenburg. In general, Petty's minor corrections have been incorporated without notice where they agree with the later version recorded by Oldenburg, and only major addenda have been placed in square brackets to indicate the evolution of his thought. For the religious background to this attack cf. J.Redwood 'The fear of Atheism in England from the Restoration to Berkeley's Alciphron' (Oxford, D.Phil. Thesis, 1975).

1. B.H. MSS 6, Section 3, Letter 76, 16 March, 1675. 'L.M.' to Arthur Annesley, Earl of Anglesey, and forwarded by him to Petty.

My Honor'd Friend,

I receaved your Letters and ye Bookes you sent and (with my Service) returne my thanks. The letter you mention is no news here, I saw it a fortnight since and everybody has it. I thanke you for the discourse you sent me, but am sorry so ingenious a person should write, or others should approve it. For y^{t} I may truly (and sub sigillo to you) say w^{t} I thinke and know; though there be severall things in it ingeniously said, yet there be too severall things highly irrationall and indeed most Metaphysicall Nonsense, and somethings (I feare) impious, if not plainly Atheisticall.

We are told. pg 15. That Place is ye Image or Phansie of matter, or matter considered. If this be true then:

1^{o} Seeing all such Phansies are only in ye soul, ergo To be in a place is to be in a phansie, and therefore, in ye Soule, where all such phansies are, and cannot possible be elsewhere.

2^{o} Motion (he saies p. 16) is change of place. Now, if Place be phansie, then if ye Sun changes its place, it is only a change of Phansie, and a change of Phansie will be a motion or a change of place. And then (if men change their Phansies, who only have their Phansies to change) ye sun may Stand Still, and ye earth move. For (you know) there have been, and still are, [those] who strongly Phansie ye Sun to Stand Still, and ye Earth to move, and others, who as strongly Phansie ye contrary. Now I would faine know w^{ch} of their Phansies is ye place of Sun or earth, and (if either) why ye one more than ye other? And if neither, then place is not a Phansie (as is pretended) and therefore ye definition itself is but a Phansie, and a wild one too.

3°. we are told also (pag 15) yt a place, is matter considered. ergo. If matter be not considered, it is no place. ergo. Horse or man, sun and moons, and ye world, when not considered, are in no place, and therefore nowhere; for: quod nusquam est non est.

4°. He tells us there (pag. 15) That quantity is ye Phansie of place and. ergo. all quantity must be where ye Phansie is, and Phansie can be nowhere but in ye Soule (which being a spirit is capable of none) and ergo. no quantity can be (estra anima) in any body whatsoever.

5°. To say yt place is matter considered; is to say, yt ye place of a Dogg, is a Dogg considered: and then all those things in ye world wch are unknown to us, and therefore cannot be considered, must therefore be in no place, and therefore not in ye world.

6°. He saies (pag. 17) (i) That ALL the FIRST matter of ye world are Atomes imutable in magnitude and figure. (ii) that many of ym joyn'd make a visible object. (iii) That this juncture is made by their own INNATE motion. Now:

(i) How will this agree wth Moses, Gen. 1. do you judge?
(ii) If such Atomes be first matter of all things, and by meeting of many of them all visible bodies be made, and they meete and are joyne'd by their owne innate motion, then 'tis evident Adam was made of such Atomes, and they mett in him (not by God's apptmt, and divine creating power) but by their owne innate power. And so Epicurus, (a Pagan Philosopher) and his Hypothesis shall have more truth and credit than ye divine History of ye creation by Moses. And how farr this (if believed) may make for Atheisme, a denying of Scripture, and ye divine power, and providence of our infinitely good and gracious God do you judge?

7°. Certainly, if Atomes (or matter imutable in magnitude and figure as he saies) be ye first matter of ye world, they must of necessity be either:

1°: Eternall, without [end] or:
2°: Temporall, with a beginning. (a)

To say that these Atomes are Eternall is to deny ye Christian Creed:

(a) Symbolu Athanasiis, in our Liturgy (and all Christian Churches) receaved in our Articles, Art. 8°.

(a) wherein we say (and should believe) yt there is but one Eternall. And if we had no Scripture, yet nature and ye undoubted principles of our Naturall reason tell us, and efficaciously, demonstrate, yt there can be but one Eternall. For wt is Eternall, of itselfe, and wthout all beginning, must (of necessity) be infinite, (for nothing can give finitude or bounds to itselfe; and wt ever is Eternall cannot possibly haye anything before it, to give it bounds, (and 'tis more impossible, yt wt is after it, and Temporall, should give bounds to an Eternall being): Soytif those Atomes be Eternall, and infinite (as they must be if they be Eternall) then they must be so many Deities or Gods; (for nothing but God can be Eternall and infinite) and then consider how many Gods we should have: even as many as there are of those Atomes.

(b) (i) Now he tells us (pag 124) that perhaps a million of those do not make up one corpusculum or visible body; and then how many millions must go to make up all ye corpuscula and corpora in the world, will be a hard worke for him, or anybody else, to number.

(b)* In minimo corpusculo contineantur multae Atomozum Myriades: Viz Philosophiam Epicuri: per Gassendi. cap 6. pag. 39. Edit. Londini Anno 1660

He then, who saies, those Atomes are Eternall, brings in A Multiplicity of Gods, and so denies the only true God; for more than one true God there cannot be.
(ii) He saies these Atomes have magnitude and motion (pag. 17. 18) w<u>ch</u> no eternall and infinite thing is capable as.

(c) Aristotle (from naturall principles) has evidently provd. But if he say (and nothing else can be sayd) that these Atomes are temporary, and had a beginning; looke, w<u>n</u>, and by whom did they begin? it is said by him (pag 17) that they were the FIRST MATTER of the world so they must be before the world: (as the matter of an House must be, before an House can be made of it. But if Moses say true (Gens 1.) In ye beginning God created the heaven and ye Earth (etc) No mention of Atomes, of which Heaven and Earth were made; Heaven and Earth were Created, (scvies Moses) and all Jews and Christians say, that was Ex nihilo ex Atomes aut materia ulla praexistenti: sed a page rugas, quae Christianum Philosophia, ne sapiunt, sed aethium aut Epicurus qui Creationem (ne virtute quidem divina) ...

(c)* Aristotle Metaphysicorum lib: 14. Cap.6. et Naturall: Auscult: lib.8. Cap.25

(d) possibilem esse negabat; sunt Apinaetrique et si quid vilius istis, quas referre pudet et piget refellere. Pray pardon this impertinent extravagance.

(d)* Vid: nota Gassendi ad eatiem. cap.S. Syntagmatis Philosophiae Epicuri pag 37. supra citat.

I am troubled (nor can I without some sorrow or impatience speake or thinke of it) to see the Scepticisme (to say no worse) which secureley thrives in our Miserable Nation; while some dare professe and publish irrationall and wild Notions in Philosophy and divinity too; To ye great prejudice of our Church and truth and gratification of our Adversaries (especially those of ye Roman faction) whose worke wee foolishly do for them (quid Ithacus vellet) and (wthout hope of reward or thanks) ruine ourselves gratis whilst others (by Authority and Duty) obliged to suppresse such opinions, and punish their Authors, betray their trust and truth; and either knowing, licence (which I am loathe to thinke) or negligently permit such Apochryphall and erronious positions to be published, in veritatis damnum et Ecclesiae Anglicanae scandala. God Allmighty be mercifull to this Bleeding Church (and nation) and to every true member, of either of them, to yo<u>r</u> selfe and

(Sir)

Your ffaithfull Servant,

*March 16, 1674 L.M.

* [In the Royal Society copy, the letter is dated March 16, 1674/75]

2. B.H. MSS 6, Section 3, Letter 61. Petty to Arthur Annesley.

3° Aprill, 1675. An Answer
to ye Paper sent by my Ld. of Anglesey.

3° Aprill, 1675.

My Lord,

The paper yo.^{w} gave me this Morning shewes the Author of it to bee as well a Learned and Witty Man, as a good Member of our Anglicane Church, and therefore, though Hee calls Mee Irrationall, Nonsensicall, Impious and Atheisticall, I doe in Christian Charity forgive such his Unbrotherly and Unphilosophicall Dealings and doe pray God to bring unto the way of Truth all such as have erred and are deceived, according to that pious prayer of Our Letany.

As for the dispute I confess Myself not able to follow him, in the subtility of his Many Arguments, But doe at first, crosse the Cudgells, and allow him to bee a better Disputant then I am for Ille Scholas Sequitur, sensibus utor Ego. But I shall repeat and Explayn my Doctrines with a few more Words, then I us'd at first - Nam dum brevis Esse laboro Obscurus fio -

Wherefore Hopeing to bee allowed as many lines wherewith to Explicate Place, Quantity, Motion first Matter, and Innate [Motion] as the Learned Gentleman, hath read of Volumes concerning ye same, I thus begin againe viz^{t}:

1° God created Heaven and Earth, that is, all Things and consequently ye first Matter of them, whether atomes or other Which Doctrine of Moses Gen: 1. 1. agrees exactly with what I sayd, in My Title-Page: Pondere Mensura et Numero Deus Omnia fecit.

2° God haveing Made Man of Earth, and afterward Created into him ye Spirit of Life, The ratio formalis whereof is Thinking (for Des Cartes sayes that Man is Res Cogitans [and labours to prove even his owne Being from his Thinking and saying Cogito, Ergo Sum, and for that thinking], Imagining or Phancying is all One); Otherwise then as ye word thought is English; Image Lattine, and Phancy Greeke, I presume that by My taking thought for My next principle of Ratiocination, I do therein exactly agree not onely with Descartes, but also with Moses, And chiefely wth the Comon Reason of the World.

3° What then can bee the next Principle but Matter, for what were thinking without Matter to think upon?

4° Haveing I say in My Title Page, fixt God for my first Principle, and in ye 14 Page taken Thought and Matter for the 2 next (as More easy and familiar to the Meanest Capacityes than any Other, and as being the Body and Soule of Ratiocination) I proceeded in the 15 Page to say, that Place was the Image, Thought or Phancy of Matter; Or Matter Considered as such an Image; takeing it, for a fair way of proceeding, to define Place by My 2 Next Immediately preceding words or principles; being such as all Men understand, if they understand anything at all. It remayns Now to shew, How that ye same way is not onely handsome and faire, but also true and solid: for supposing a Seale to represent Matter, the which, if it be Impressed upon wax, and taken off agayne, I say that the fovea which Remaynes is as well the Place as the Image of ye Seale or

Matter; and so because Qua eidem conveniunt, conveniunt inter se, I made no scruple to affirme that the Place of Matter, was the Image of the same, or vice versa, That the Image of Matter is also its Place. Quod erat probandum. Moreover, Considering the same Place and Matter (secundum plus et minus) to bee equall, because the same; I tooke this Image or Consideration of Place to bee alsoe quantity, viz the Quantity of the matter, [for ye Inner Superficies of any Cask, Mold, or vessell is ye Image, Shape, place and Measure of ye matter contayned in it. And soe One Superficies is 3. viz:- v.addicamts, Shape, place and measure, by 3 severall wayes of considering it, upon these grounds]. I did sett forth this Doctrine now Impugned, of place and Quantity, as more easy and sensible than yt. of ye Schooles, as Change of Place, is also a More Edifying definition of Motion, then Actus Entis in potentia, quatenus in potentia.

Now, if it bee not enough for the Churches and Scriptures' vindication to have said (Deus omnia fecit) I shall reinforce the same, wth an other Scripture, which is that (God is All in All) The Meaning whereof, I with Submission conceive to bee, that God is all Power, All Vertue, All Energy and All Motion in all Things and in All Beings whatsoever. And consequently That from him proceeded Even that Innate Motion which Wee did attribute to Atomes; and from him alone, was that power derived, whereby those Atomes (or most Commodious Element) were beautifully, wisely and infinite variety joyned together, in the fabrick of the Universe, and of all its severall parts. [In ye meantime, I wonder yt Since Wee allow unto ye sun and Innate Moon, we may not allow ye same to ye smaller parts of ye World, and why it should bee mere Atheisme to say Motus Innatus, than Calidum Innatum (than w^{ch} Nothing is more common and authentic) and why to say that ^{a} Thing is Natus, or Borne, should inferre Independency and deny all of Him, whereas Nasii inferres parents ye creatures of God, for I would not have Man Comment upon Christian Philosophers) to put such Interpretacons upon Each others Words Unlesse twere Improbable to find out any other] Now, haveing thus to the usuall and negative description of God by high Eternity, Infinity, and Incomprehensibility, added ye forementioned positive Declaration of his Immense Power, grounded as well upon Divine Revalation as upon sense and reason, I shall wth reverence to his dreadfull Ma^{ty} adde something both in Meater and Rhyme concerning the same, viz:-

Quod Deus est, scimus; Si quid sit scire velimus; Ultra Nos imus.
Sed quod sit sumus et Imus, Ultimus et Primus, Scimus; Phisscire Nequimus.

And thus wth My Duty to Almighty God, Conformity to his Church, and wth My Joy to find such a jealousy for the Honour of both in yo^{r} Ld pps freind. I quietly contemne the haveing been called Irrationall, Nonsensicall, Impious and Atheisticall and remayne,

Yo^{r} Ld'pps

13^{o} Aprill, 1675 verte

Postscript.

If I did not think this Gentleman, to have meant well, and so to have been yo^{r} Ldpps freind, Or if I had suspected that he wrote his paper out of an Itch and humour of Contradiction, rather than out of a Sincere affection to Truth and Piety; I had handled him after an Other Fashion, for I think I could have Demonstrated a great part of his Paper, to have been absurd, and could have turned all the rest into Redicule, Or at least I could have prov'd this Gentleman to have been Anti=Christ.

(vi) The Petty-Wood Correspondence

By 1674 Dr. Robert Wood was one of Sir William's oldest friends, and as a result, when separated geographically, they usually maintained a regular correspondence. The letters ranged over current affairs, business matters, family concerns and, where appropriate, intellectual pursuits that come under the general heading of natural philosophy. Early in 1675 Petty sent copies of the Discourse to Wood in Ireland, asking him to circulate them to those common acquaintances who might find the treatise interesting. The author also invited the comments and criticisms of this Irish audience for which Wood acted as intermediary and spokesman. Owing to the 'mixed' nature of the contents, only those sections which relate to the reception of Petty's treatise are presented here. It should be remembered, however, that such a process of selection is necessarily artificial in that the writers may have placed equal value on other issues discussed in their correspondence. With regard to the ordering of the letters, it will become apparent that they are not always placed sequentially, i.e. in terms of their date of composition. This is due to the vagaries of the contemporary postal system and is based on internal evidence from the correspondence that indicates the non-arrival or successful delivery of particular letters. Unfortunately, many of Petty's replies to his correspondent's objections remain unlocated at present, and it is necessary to use Wood's own comments and references to Petty's letters as an indication of what was contained in them.

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1. B.H. MSS 19, pp.374-375. London to Dublin. Petty to Wood

To Dr. Wood, 3 Ap.^{11} 1675.

Dr Friend,

I sent severall of my Books or Lectures made at Gresham College into Ireland, by Mr. John Davis & among them one to yo^{r} self & expected to have heard something from yo^{w} thereupon, w^{ch} was the Cause of My Silence. But now forasmuch as I cannot here any thing, neither of him nor My Books these are to know how, yo w. doe, What Matters are in Ireland upon ye Anvill ... '

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2. B.H. MSS 6, Section 3, Letter 60: Dublin to London. Wood to Petty.

The relevant section of this letter, dated 30 March, 1675, begins at the second paragraph: The Lord Lieutenant of Ireland at the time was Arthur Capel, First Earl of Essex

'My Lord Lt. asks sometimes how you do, and w^{n} I last saw him, whether you came over this spring; and bad me tell you that he had yo^{r} Book by the post. I found also he had sent it to ye Solicitor Gen. before the others to me came over, w^{ch} 'tis more than time I should returne you at least my thanks for, as indeed I do very heartily. I find here they are more apt to censure than understand it (even ye. Sol. himselfe told me he was angry wth you, for saying a Child of 12 yeares old might do in one houre w^{t} he found he could not do in many) Among others in this bad air I also cannot disowne some degree of Infection. I have read it all over at least twice, but yet I cannot say I have so fully considered above 3 or 4 Chapters, as I hope to do. viz. that about the strength of Timber and Motion of Horses, Life of Man etc. concerning w^{ch} I shall presume to offer you some Reflections, that you may judge whether I understand yo^{r}. Doctrine or not.

Yo^{r} Atoms tho' very small are yet too big for me to swallow, and indeed I wonder how any Mathematician can, who understands Quantity to be infinitely or sufficiently divisible: tho' I confess there is as much reason for period[is]ing the Littleness as Greatness of Body.

In yo^{r} Definitions you say Figure is Quantity and Situation considered together. I should rather say (and more conformably to Euclid and others) Quantity and Termination or Limitation considered together: for situation seemes not at all Essentiall to Figure. You say Place is the Image or Fancy of Matter w^{ch} p^{haps} some others call Space in ye imaginacion. Againe, you define Right to be the Image of Possession, and is to it as Place to Body. Wherefore if Right should be defined the Fancy of Possession, w^{t} would the Lawyers, such as Jack Keating, say to it? But quo jure do you define Right w^{n} you make no use of it in the whol Book? you'l tell me you will elsewhere, to w^{ch} I say Amen.

In the 11th Instance of the Life of Man, tho I hugely Like all you say as to ye yeare 16 and the yeares compared wth it etc. yet the rest of the Chapt. is either not true or not proved. E.g. you say 'tis found by experience y^{t} there are more persons living of between 16 and 26 yeares old than of any other age or decad of yeares in the whol life of Man: whereas the Obs. on the Bills of Mortality demonstrates that there die at least 1/3 of mankind under 5, and consequently that there are at least 1/3 living under that age to supply that mortality. Ergo. Pag. 86. l. [line] 3. w^{t} you say of a number between 4 and 5 the Root of 21 etc unto line 13th, seems to be but opinion wthout ground.

I shall end at present wth one Instance more than there enumerated by you, and with w^{ch} I fancy you might have begun. viz that:

The Contents or Quantities of like Figures (whether Superficiall or Solid) are in Duplicate Proportion of their respective Bounds or Limits: And These in subduplicate of Those. I need not suggest Examples to you, but need to crave yo^{r} Pardon for all this boldness I have taken; in w^{ch} not withstanding I had no other or more wanton end than to express my Gratitude for the great pleasure and satisfaction I have felt in perusing this yo^{r} New and Excellent Discourse - Ego nunc me denig .. natum Gratutor etc. vale,

Yo^{rs} intirely,
R.Wood.

For Sir W^{m}. Petty Kt.
at his house in Portugall Street,
London.

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3. B.H. MSS 6, Section 3, Letter 62. Dublin to London. Wood to Petty.

This letter probably arrived in London before Petty's reply of the 10 April 1675. (see letter 4. below).

April 6, $\overline{75}$

'Dear Sir,

In my last of the 3rd instant I was too morose especially about ye 11th instance in the Life of Man etc. viz I would have put a dele upon the first 6 or 7 lines etc. whereas I must now acknowledge I had no reason to find fault wth yor sense, and that the WORDS only in the second line being a little altered, viz (It is found by experience that fewer in proportion die of the persons living between 16 and 26 yeares old than of

any other Age etc) all the rest of y^{e} Chapter is very rationall and coherent. And the reasons you give in the next page speake your sense to be as I have said as to y^{t} purpose, though I find nothing to ye contrary but y^{t} what you say of ye decade between 16 and 26 may as well be said of that between 26 and 36, as to gout, stone, and other infirmities of old age. Besides, that Disease called the Consumption seemes to be predominant about 25.

I should be heartily glad of and thankfull for ye Acct you mention of the parish of above 330 soules, the summe of whose pticular Age, I find about 5000, or upwards. At least I would know the arith metically - middle yeare or age, above and under w^{ch} the number of p'sons is equall.

I have also since my last perused again the Chapter of Sounds and Smells and according to my calculation in page 75. ([line] penult [imate] for 64 I read 58. and consequently pag. 76 for near 200. r.[read] 175. But because Sounds, and Smells seeme to me to move spherically or if you will hemi-spherically upon the surface of the Earth, why should not the distances at w^{ch} they are perceived be rather the cubic than square roots of ye matter, out of w^{ch} they are imitted?

Yor's. R.W.

For Sir W^{m} Petty, Kt. at his house in Portugall Street, London.'

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4. B.H. MSS 19, pp.375-377. London to Dublin. Petty to Wood.

'To Dr. Wood 10 Aprill 1675.

Dear Friend,

To yours of the 30 past. I never recd Letter from you wherein Mr. Follet is mentioned. My wife is comeing over for Kerry, Let him Turn his....

for Kerry, I will give her Instructions for Transacting with him N.B. I will have security for his just accompting and prying what is Due etc. for

whereof I have formerly suffered.

Now to ye Objections.

which I speak of Willingly, because comeing from a sure friend.

1. I have for Experimt made severall Children under 12. of both sexes to understand Duplicate and Triplicate proportion in an hower.
2. I doe not say Atomes are points, but on y^{e} contrary suppose 3 points in ye least of them, and can admitt a million more. Onely I would have the first matter so small, as to need no further Hewing or Chipping; As Bricks make Buildings, like those of hewn stone, with little cutting and if ye Bricks were smaller, None need ever bee cut or broaken or rub'd.
3. I stick to my Definition of Figure by Quantity and Situation, for in surveying our Chain Showes One and our Needle the other and both produce a perclose or Termination.
4. As for my Defi: of Place and Quantity. Consider that y^{e} inner Superficies of a vessell or Mold, is ye Place, Image and quantity of what is conteyned in it, which 3 are but one diversly considered.
5. The Definition of Right was Impertinent in in Salviam Custodiam onely.

6. That in y^{e} Parish I quoted 'tis True that as My Informer told Mee. that there was More of betweene 16 and 26 than of any other decade but hirondo noti facit ver. This Instance was not sufficiently dilated upon, but shall bee better: Interim I ask you: Is ye salubrity greater where your Numerous Index mencioned in that Instance is great or small?
7. I grant that some things in that Instance are gratis dicta, and Commityes offered to examine us by Experience or Reason.
8. The Instance you add, I really had made the first, with usefull Applycations, but put it out agayne, because my Lecture was too long [even] without it.
9. As for ye Correction sent Mee, I thank you. Many of y^{e} faults were not Mine, and Others are according to My usuall way of grosse Draughts of New Conceptions. Polishing is not my way.
10. As for Mens Concurring [with] Mee, for not understanding Mee, Tis a sign of Enmity or Envy, for if I were a popular and beloved person, people would applaus my writing y^{e} more for their little understanding them. So y^{e} Report of y^{e} Councill of Trade, so much Exploded and thought criminall by some, is now in every great Mans Archives.

Adieu vive et vale.'

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5. B.H., MSS 6, Section 3, Letter 63. Dublin to Lond. Wood to Petty.

'Apr. 18. $\overline{75}$.
For Reply to yor^{s} of the 10th:

1. Many $\overline{\text{p}}$ticulars in my former objections were not my owne opinions, but a Narrative of other mens, viz to yo^{r} 1 ff [1] I do not at all doubt but many children under 12 may be made to understand 2 plicate and 3 plicate proportion in an houre: and I once had a scholar who I beleeve might have done the same under 8. The like as to yo^{r} 4 ff about the Def. of Place and Quantity. I did and do agree with you. And to yo^{r} 5th ff or Def. of Right I said Amen before. And for your 6th and 7th ff about Longevity etc. you'll see by my second letter of the 3d instant how little I dissented from you. For yor 8 ff of the Instance I would have added, I can not but applaud myselfe for jumping so with you. And hope hereafter to see those usefull Applications you mention. Lastly for yo^{r} 10 ff That mens' censuring you for not understanding you, is a signe of enmity or envy and I prefectly concurre. But:

2. In yo^{r} 2 ff concerning Atoms, by wch you seeme to understand such very small figured Bodies wch you say need no farther Hewing or Chipping, as Bricks etc make Buildings. I grant and beleeve that much of the first matter may be such; But then I say farther that in the Fabrick of the world there must also be some stuff like Mortar, not only divisible but actually divided in infinitum, if there be no vacuum (as I see no necessity of admitting it;) Especially where those Atomes or Bricks are supposed to be in constant motion.

3. As you stick to yo^{r} Def. of Figure by Quantity and Situation, in yo^{r} 3 ff So I must yet Stick to my Objection; for tho' you instance very ingeniously that in surveying, the Needle shewes the situation by w^{ch} a like Figure may be made: yet can I not understand that that Situation is essential to that Figure but that the Figure may without it. [For] yo^{r} Atomes keep their Figure (or els [there] were no Atomes) yet, being in motion, change their situation continually. If you can convince me that I am out in this, I shall turne a perfect Sceptic and doubt of everything.

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[1] i.e. Paragraph 1 of Petty's letter to Wood dated 10 April, 1675.

4. In yo^{r} 9th ff you say, and that very well, about some Corrections I sent, that Polishing is not your way. And I say too 'Twere unfit so good an Architect should be employed in hewing of Stone or rubbing Bricks, yet even that inferior worke (w^{ch} may perhaps be done by others who would be glad of such employment) ought not to be neglected. Nor in that Building so commendable in w^{ch} some Stones will not endure the weather, tho' the Building may stand wthout them, or where others lie so that we stumble at, or breake our Heads against them.

But all my Corrections were not so serious ones as you might see ye very first. I am so much in love wth yo^{r} second instance that I would have it crown'd wth a Garland or Corollarie and what think you of such an one as this viz:

The Strength of like Timbers etc is in proportion to their respective surfaces, viz. as surface to surface, so strength to strength ...'

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6. B.H., MSS 6, Section 3, Letter 64. Dublin to London. Wood to Petty.

'Dublin May 15, $\overline{75}$

Honoured Sir

In yor's of the 27 past, you bid me consider well:

1. "That if I allow 3 points in every Atome prov'^{t} - etc." there needs "No Mortar to make a World of ym, For their Motions will bind ym etc. I have endeavour'd to consider it, and at length must acknowledge my want of understanding.

2. Nor do I understand the necessity of the consequence That "If the bulke of the matter of the world be Atomes, and many of them globular, Then there must be intersperst Vacuola." Answerable. For those little angular spaces may be filled with smaller matter, like mortar, divisible and divided infinitely, and accomodating it selfe to all the imaginable corners of the globular Atomes. W^{ch} Infinity is much more intelligible to me (having mett with so many resemblances (at least) of it in Geometry and Arithmetic; than those Vacuola, that is say Nothings, wch yet must be supposed to have reall properties of Length, Breadth and Thickness etc.

3. You still insist that "Figure is made of Quantity and Situation, as matter of cleer sense. For (say you) Is not a Square 2 North and South parallell lines crossing 2 other equidistant East and West lines? etc." To w^{ch} I answer If you suppose the Square to be moved upon its Center in the same Plain 45 degrees, it will then be 2.N.E. and S.W. lines crossing 2. other equidistant S.E. and N.W. lines and yet remaine the same Square still in another portion or Situation and consequently that the Situation is not essentiall to the Square or Figure.

4. You say, smells and sounds operate in duplicate proportion in the same plaine N.B. I Ans. that the matter of Smells (and Motion) of Sounds being emitted Spherically, how can they be supposed to operate otherwise than in triplicate proportion? N.B. unless you would have me imagine y^{m} to be compressed like a thin cheese betwixt the earth and Clouds etc.

I shall now shortly give myselfe the satisfaction of further entertainment, by embracing or comprehending some more of yo^{r} Booke ...'

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7. B.H., MSS 6, Section 3, Letter 70. Dublin to London, Wood to Petty, letter dated 28 August, 1675. The section which relates to Petty's Discourse is located near the end of the letter:

Having now long expected yo^{r} Philosophicall Response I shall venture to Shoot my bolt once more. viz

1st. That smells, sounds etc are emitted spherically, or rather, as they meet with winds and other accidents, in an oblong or ellipticall spheroid and consequently are not within the duplicate Kingdome.

2d. That situation, being a relative accident of Body, and relating most commonly to remote things as starrs, points of the Heavens etc. is not so proper to define Figure by, as Termination or its owne boundes where it meets with other Body or Bodies.

3. That Atomes and vacuola on one side, and Body infinitely divided on the other, are but severall Hypotheses. And (besides the metaphysicall reason ag^{t} vacuities heretofore hinted [at]) the former seemes less curious or subtile etc. I hope you'll pardon these abrupt hints. ...

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8. The following letter, from Petty to Aubrey, contains his opinions on points raised by Wood in the preceding letters and is therefore included in this section of Appendix vi. It is interesting to note how Petty's attitudes had developed in the three intervening years between publication of the Discourse and the summer of 1678. The letter is in the Bodleian Library, at Aubrey MS. 13, f. 100. Copies are also in Aubrey MS. 10, f. 44, and Brit. Mus., Egerton MSS. 2231, ff. 90-91. An inaccurate transcription of the letter has been published in: Aubrey on Education, ed. J.E.Stephens, op.cit., p.108.

Dublin, 29 May 1678.

Sir,

I have received your kind letters for which I thank you, As for the Reprinting [of] the booke of Taxes, I will not meddle with it. I never had thanks for any publick good I ever did Nor doe I owne any such booke. As for that of Duplicate Proportion, I take Mr. Lodewick's paynes to put that discourse into the real character to be an honour to Bishop Wilkins and myself, but doubt of its acceptance in the world.

As for the opinion of Dr. Wood's and others, that the Emanacons of Visibles and Audibles etc should have been in triplicate (not duplicate) proportion, I say that neither is demonstrably true, but that duplicate doth better agree both with reason and Experience. Carpenters and Wheelwrights say that the diameter is to the Circle as 1 to 3. Others say better as 7 to 22, but neither is exact, yet both serve their turne. So what I have done in that discourse was only to keep men from grosse errors and for bringing them into the way of exacter truth. I hope no man takes what I say'd about the mocon and burthen of horses and the living and dying of Men, for Mathematicall demonstracon, Yet, I say they are better ways of estimating these matters then I ever heard of from others. I hope better are now found out, But there are 2 or 3 real mistakes in that treatise of which more with ye next.

I am, yours and Mr Hooke's,

Wm. Petty.

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MS.	Oxford University Archives, Q.b.18		'Registratum Congregationis 1648-1659'.
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2) The Petty Papers at Bowood House, Wiltshire :

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2. Poeticall Amusements and Miscellaneous Papers.
3. Medical Studies.
4. Drafts of Political Essays concerning Ireland.
5. Letters to Lady Petty.
6. Section I (Letters to John Petty in Ireland)
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   Section III (Further letters to W.Petty)
7. Letters from Sir Robert Southwell.
8. Letters from Lady Petty to her children, etc.
9. Letters 1663-1683 (mainly to Sir R.Southwell)
10. Letters 1682-1688 (" " " ")
11. Miscellaneous papers bought from Thorpe 1834 Vols.I & II.
12. " " " " " 1834
13. Letter Book of John Petty to Sir William Petty: 1671.
14. " " Rutter to " " " : 1672.
15. " " Rutter to " " " : 1673.
16. " " Thos.Waller to " " " : 1671-1674.
17. " " Thos.Dance to " " " : 1685-1686.
18. " " Thos.Dance to " " " : 1687-1700.
19. Sir William Petty's Letter Book July 1672 - November 1675.

20. 21. Manuscript volumes copied by Henry Schultes in the 18th Century from papers relating to Sir William Petty's Naval Experiments.

22. MS. Volume belonging to Henry, Lord Shelburne, with exercises and diagrams relating to nautical geometry and navigation.

23. Sir William Petty's History of the Survey of Ireland in 18 chapters.

24- 29. 5 Volumes of the original Down survey maps (in manuscript with hand-drawn plates).

II: Boxed Manuscripts

30. A. Lists,schemes, tables relative to Government,Revenue,Trade.

31. B. Ireland Miscellaneous (temp. James II).

32. C. Ireland Miscellaneous.

33. D. Ireland, Kerry Quit Rents.

34. E. Government, Parliament, Revenue of England, Navy Papers.

35. F. Irish Land Settlement & Survey.

36. G. Manufactures,Trade,Forests, etc.

37. H. Royal Society.

38. I. Religion.

39. J. Sir William Petty's Papers (copies,various notes relating thereto).

40. K. " " " " (Transcripts and MSS.. of Printed Books).

41. L. Wooden Box containing Census Returns (1654-1659) from Ireland.

42. M. Sir William Petty's original Deeds, Will and purchase of Lothbury.

43. N. County Kerry Woods and Planting, 1697- .

44. O. County Kerry Glanerought Lands, 1650-1720 .

45. P. 16th and 17th Century Charters relating to Lothbury (purchased by Petty in 1659).

46. Q. M.S. Life of Sir William Petty by William, Earl of Kerry (1811-1836).

These papers have recently been catalogued at the Bodleian Library. This listing was not available at the time of composition and the older, somewhat irregular reference system, devised by the Marquis of Lansdowne (editor of the Petty Papers etc.,) has been utilised. In the footnotes the abbreviations for Bowood House manuscripts are as follows :

1) For bound volumes : B.H. MSS (1 - 29) item (or no.).
2) For boxed papers : B.H. MSS (30 - 46) Box (A - Q) folder (i - n) item - .

3) Brasenose College.

MS. Vice-Principal's Register, 1594 - 1696.

4) British Museum.

Additional MS. 4811.	Containing Petty's 'Advertisements for the Dublin Philosophical Society'.
Additional MS. 6782.	T.Harriot's mathematical note-book.
Additional MS. 6788.	T.Harriot's mathematical note-book, 1599-1600.
Additional MS. 15,948.	J.Evelyn's correspondence book.
Egerton MS. 1324.	Commemorative album for Dr.C.Arnold, c.1651
Harley MS.3360.	Hobbes' treatise on optics, c.1646
Lansdowne MS. 691.	Dr.N.Grew's tract on improvement, c.1702.
Lansdowne MS. 1228.	Containing Sir W.Petty's speech as a Judge of the Admiralty, c.1676.
Sloane MS. 243.	Containing a copy of Petty's treatise on dyeing.
Sloane MS. 360.	A satire on the Double-Bottom boat.
Sloane MS. 427.	Hartlib papers containing Symner's letter, c.1648.
Sloane MS. 496.	Dr.H.Power's chemical notes.
Sloane MS. 1351.	Dr.H.Power's memoranda.
Sloane MSS. 1353-1358.	Dr.H.Power's memoranda.
Sloane MSS 1941-1942.	Dr.N.Grew's miscellaneous papers.
Sloane MS. 1949.	Dr.N.Grew's medical prescriptions.
Sloane MS. 1950.	Dr.N.Grew's miscellaneous papers.
Sloane MS. 2574.	H.Schere's marine experiments, c.1670.
Sloane MS. 2903.	A.Hill, philosophical papers.
Sloane MSS 4278-4280.	Dr.J.Pell's miscellaneous notebooks and papers.

5) House of Lords.

Main Papers, 25 February 1647 - 1648. Containing W.Petty's petition over the double-writing instrument.

6) Magdalen College, Cambridge.

Pepys MS. 1074.	Mr.Dumer on nautical improvements.
Pepys MS. 1731.	'Of ..... Navarchi' by S.Fortree.
Pepys MS. 2643.	Papers on nautical experiments.
Pepys MS. 2870.	Containing proposals for the national registration of births and deaths.

7) Mc Gill University, Montreal, Canada.

Osler	MS. 7612	Sir W.Petty's correspondence (notebook) c.1673 - 1687.

8) National Maritime Museum, Greenwich.

MS.SP B/16	Volume of papers on naval questions and twin-hulled ships by Sir W.Petty.

9) Public Record Office.

SP.18. Vol. 2.	W.Petty's appeal, c.1649, to the Council of State over 'Double-writing'.

10) The Royal Society.

MS. Boyle Letters vii.	Boyle's miscellaneous (early) letters and papers.
MSS.Classified Papers,iii.	Material on crafts and mechanical skills.
MSS.Classified Papers,vii.	Architecture, Shipbuilding etc.,
MSS.Classified Papers, x.	Containing R.Melish's tract on improvement.
MSS.Classified Papers, xxv.	'Trade'.
MSS.Classified Papers,xxiv.	'Hooke,Collins,Oldenburg MSS,1660-1740'.
MSS. D.M.5.	Containing material on the state of the Society, c.1674.

11) Sheffield University, Hartlib Papers.

These invaluable papers are currently being catalogued. The present writer was able to use this as yet unpublished (and incomplete) list. This massive archive contains over seventy-five bundles, grouped together in what appears to be their original order of receipt. Within each bundle are smaller subsets, and within these, foliation is now being added. This has produced an irregular, yet effective system of reference which has been utilised whenever the cataloguing process was complete. The following footnote procedure has therefore been adopted :

[eg.] Hartlib Papers, [bundle] xvii, [subset] 1, ff. 2r - 3v.

A singularly important source within the papers are Hartlib's Ephemerides, which run from 1643 to 1660, though not without some breaks and periods of more sketchy recording. They occupy all of Bundles xxviii, xxix, and parts of other bundles (including xxx). For the purposes of the thesis, Professor Turnbull's typed transcript of this near-illegible and erratically organised material has been followed. Turnbull's mastery of Hartlib's difficult hand ensures that this transcript is a useful and accurate substitute for the manuscript, while his reproduction of Hartlib's complicated system of foliation allows speedy reference to the original. Reference to the Ephemerides is as follows:

[eg.] Hartlib Papers, MS. Ephemerides, 1648, O-P3.

12) Worcester College, Oxford.

MSS. 4.9. (number 88)	Aubrey's mathematical notebooks.
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