ALLEN G. DEBUS (*)

History of Chemistry: Key to Modern Science (**)

If we were living in late antiquity — say the fourth or the fifth centuries after Christ — rather than today ... and if we had an interest in the intellectual progress of mankind ... we might well have written a different history of antiquity than we do today. Such an historian if he lived in Europe would most likely have been a Christian who considered the revelation of God's truth and the salvation of man's soul the chief end of our understanding and of our endeavor here on earth. His finished history would emphasize the development of Christianity and the theological debates that were so much a part of his world. As we know, such histories do exist from that period and from the medieval period. In such works the accomplishments of the Hellenistic mathematicians and astronomers and the medical work of the contemporary physicians play little or no part. The point is that historians normally look at the world about them and search past records to establish those steps that have led to the present. And what is considered important in one age may be considered relatively unimportant in another. We may then be presented with radically different interpretations of the same period.

This problem of historical interpretation has a real parallel in the development of the history of science in this century.[1] The philosophes of the eighteenth-century Enlightenment saw a real difference between traditional histories and the sciences. The former dealt with politics and wars, the obscurantism of religion and the anecdotal stories that were connected with the kings, queens and courtiers of an earlier age. Little of this contributed to our knowledge of the human spirit. But the history of the sciences was something quite different since here we could chart the progress of the human mind and our ever expanding knowledge of the world about us. Nowhere was this more evident than in the triumph of Newtonian physics which had abandoned the mysticism and magic of an earlier era. So impressive had been

(*) The Morris Fishbein Center for the Study of the History of Science and Medecine - The University of Chicago - USA.

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[1] I have addressed this problem in a series of lectures presented at the University of Coimbra in 1983: *Science and History: A Chemist's Appraisal* (Coimbra, Portugal: The University of Coimbra Press, 1984).

the success of the new mechanical philosophy by the closing decades of the seventeenth century that authors were already writing works on the debate between the ancients and the moderns. The meaning seemed to be quite clear: the ancients were the Aristotelians, the Galenists and their medieval commentators; the moderns were those figures of their century and the preceding one — figures such as Copernicus, Tycho, Kepler, Galileo and Newton — whose work had led to a "new philosophy" or a mechanical philosophy, one that had replaced an educational system founded on ancient learning. This interpretation was almost universally accepted thirty years ago and it is still to be found in many current histories of science.

But if we as historians of science write our histories to establish the various steps leading from Copernicus to Newton and then go on to interpret post-Newtonian science as positivists we are writing only one kind of history, a history termed by the British historian, Herbert Butterfield, as "Whig" history. Butterfield's goal in his 1931 essay on "The Whig Interpretation of History" had nothing to do with the history of science. Rather, he was distressed by English historians who interpreted the English Civil War of the mid-seventeenth century solely from the liberal or "Whiggish" point of view. The historian, Butterfield argued, should not take sides ...

> His role is to describe; he stands impartial between Christian and Mohammedan; he is interested in neither one religion nor the other except as they are entangled in human lives ... He is back in his proper place when he takes us away from simple and absolute judgments and by returning to the historical context entangles everything up again. He is back in his proper place when he tells us that a thing is good or harmful according to circumstances, according to the interactions that are produced. If history can do anything it is to remind us of those complications that undermine our certainties, and to show us that all our judgments are merely relative to time and circumstance.[2]

To this point I have said nothing about the history of chemistry. Although the writing of the history of chemistry has had a long history of its own,[3] those interested in the origins of modern science seldom mention it as a major factor among sixteenth and seventeenth century developments. And this may be admissable if we are interested only in the establishment of Copernican astronomy and Newtonian physics. However, if we are to follow Herbert Butterfield in history or Walter Pagel who spoke more directly to historians of science and medicine,[4] we must try to recreate the world of our authors rather than hunting only for the stepping stones leading to Newton, Darwin, Einstein or any other great figure in the sciences. If we do this we find immediately that sixteenth and seventeenth century science and medicine presents us with a far richer texture than a simple ladder of success leading to classical mechanics.

[2] HERBERT BUTTERFIELD, *The Whig Interpretation of History* (1931; New York: W. W. Norton & Co., Inc., 1965), pp. 74-75.

[3] See ALLEN G. DEBUS, «The Significance of Chemical History», in *Science and History* (note 1, above), pp. 34-51.

[4] For an assessment of Walter Pagel's contextual concept of the history of science and medicine see ALLEN G. DEBUS, «Introduction», in *Science, Medicine and Society in the Renaissance: Essays to Honor Walter Pagel* (2 vols., New York: Science History Publications, 1972), I, pp. 1-9.

If we turn to the early decades of the seventeenth century we find that figures closely associated with the development of a new science such as Marin Mersenne, Pierre Gassendi — even Johannes Kepler — were concerned about the claims of chemical philosophers who sought to replace the natural philosophy and medicine of the ancients with their own vision of a chemically operating nature. We know of the Hermetic interests of Giordano Bruno and Tommaso Campanella while William Gilbert's early interests were centered on chemistry no less than on magnetism or medicine. As for Tycho Brahe, historians of astronomy have had little interest in his belief in the importance of a terrestrial astronomy linking the heavens and earth.

But why should these figures and others have had such an interest in chemistry? At first this might seem unlikely. If we look at the late fifteenth century we find that the scientific and medical humanists sought to replace the texts in use with newly discovered and newly translated works of Ptolemy in astronomy and Galen in medicine. The first phase of a new science was to discard the incomplete texts and barbarous translations of the medieval period. Physicians in particular welcomed these new texts and praised Galen as the "Prince of Physicians". As a result, this new Galenism along with Aristotelian philosophy dominated the universities and faculties of western Europe.[3]

Two additional factors were to affect the development of the sciences in the sixteenth century. The rediscovery of the *Corpus Hermeticum* seemed to make available the genuine works of the ancient sage, Hermes Trismegistus. These texts seemed to demand a close connection of religion and a mystical interpretation of nature. And with them were associated a body of alchemical texts and works on natural magic. No less important was the Protestant Reformation which called into question not only traditional Roman Catholicism, but also the university curricula of European universities which was allied to it.

It was this world of shifting and uncertain values that Paracelsus lived in. Born in 1493 in the Swiss town of Einsiedeln, he learned something of alchemy and medicine from his father ... perhaps something of the occult sciences from the Abbott Johannes Trithemius of Sponheim ... and surely something of the metallurgical practices of the period from the Fugger mining towns in which his father practiced.[4] Nor was he ignorant of the higher education of his day since he reputedly visited many universities during his *wanderjahren*. There is neither need nor time to discuss his life here ... suffice to say that it was an unsettled one. He moved frequently before his death at Salzburg at the early age of 48 in 1541.

[3] The best introduction to Galenic medicine is Owsei Temkin, *Galenism: Rise and Decline of a Medical Philosophy* (Ithaca and London: Cornell University Press, 1973). For the role of Galenic medicine in the sixteenth century, see the essays included in A.R. Wear, K. French and I.M. Lonie, *The Medical Renaissance of the Sixteenth Century* (Cambridge: Cambridge University Press, 1985).

[4] The literature on Paracelsus is voluminous. The most authoritative work remains Walter Pagel's *Paracelsus: An Introduction to Philosophical Medicine in the Era of the Renaissance* (1958); 2nd, revised ed., Basel: Karger, 1982. Giancarlo Zanier has contributed a number of important studies of the Paracelsian literature in Italian. See especially his *L'Espressione e l'Immagine: Introduzione a Paracelso* (Trieste: Edizioni Lint, 1988) and *Medicina e Filosofia tra '500 e '600* (Milan: Franco Angeli Editore, 1983).

Here we are more concerned with the impact Paracelsus made on medicine and the sciences. But what did he believe?[3] It is difficult to summarize a complex system in a few minutes, but it is clear that Paracelsus rejected traditional learning. True learning, he thought, was based upon true religion and man might understand his Creator not only through Holy Scripture, but through the Book of Created Nature. In short, he insisted that we should go out and observe nature rather than read the texts of long dead Greek authors who had been heathens. Because of the interconnection of nature and supernature, Paracelsus placed great stress on the macrocosm-microcosm analogy. Whatever was in the great world would also be found in man. It need hardly be added that medicine was a subject closely identified with more general studies of nature.

This new philosophy of nature was to be founded on chemistry. The Creation itself was pictured as a chemical separation which led directly to the determination of the elements. In addition to his use of the traditional earth, water, air and fire, Paracelsus introduced the *tria prima*, salt, sulphur and mercury which became the favored system for most of his followers. They pictured the earth as a great distillation flask with an internal fire which accounted for volcanoes and mountain streams. A life spirit was required not only for man and animals, but for inorganic growth processes as well in this vitalistic system.

Still, it was medicine that was of most interest to late sixteenth-century chemists. The Paracelsians rejected the humoral theory of the Galenists. Rather than seek an explanation of disease in terms of a humoral imbalance, these chemists sought the origin of disease in external factors that entered the body through food or respiration and became localized in body organs. The various organs had within them certain forces or *archei*, which acted like alchemists by separating pure essences from waste. These essences were distributed where needed and the waste eliminated through the pores, the digestive tract, and the lungs. If the archeus of any organ did not function properly, the waste might not be completely eliminated, and disease or even death could result.

Seeds of disease that did become lodged in the body grew in a fashion similar to the growth of metals in the earth; that is, in the earth metalline seeds were thought to grow into a metal or metallic ore when introduced into a proper earthly matrix whereas in the human body, a disease seed would grow if lodged in an appropriate organ. It followed almost as a corollary that chemically-prepared medicines should be added to the traditional, herbal based, Galenicals. New and stronger preparations — often prepared from metals — were prescribed by these chemical physicians who saw a need for more potent remedies to combat the new and violent diseases of sixteenth century Europe.

Galenic medical cure was dominated by the belief that contraries cure: A disease characterized as hot and of a given degree must be cured by an opposed medicine, one that was cold and of the same degree; in this fashion humoral balance might be achieved. Paracelsians turned to folk tradition and insisted on

[3] Again, the literature on this subject is substantial. Here I base my comments primarily on my *The Chemical Philosophy: Paracelsian Science and Medicine in the Sixteenth and Seventeenth Centuries* (2 vols., New York: Science History Publications, 1977), 1, pp. 1-126.

cure by similitude, arguing that a poisonous disease had to be cured by a like poison. For this reason we find that the Paracelsians had a great interest in drugs compounded from mercury, arsenic, antimony, and a host of other metals and minerals. These substances were frequently used as purges, to the anger and despair of the Galenists.

Here again was a direct challenge to the medical establishment. Galenists charged their adversaries with the indiscriminate prescription of poisons. Not so, countered the chemical physicians; not only did they remove the poisonous qualities of metals by chemical preparation, they also gave careful attention to proper dosage with their stronger substances. But they could not deny that they used reagents that were originally poisons.

Consider the situation in the mid-sixteenth century. Physicians who were members of the European medical faculties felt that they had firmly reestablished the authority of Galen and other ancient medical authors with new translations as well as newly discovered texts. But now there had appeared a new group of medical practitioners who would do away with all this and base medicine on chemistry, a lowly art at best. Nor were the natural philosophers in any less jeopardy since the Paracelsian chemical philosophers raved against Aristotle and sought an understanding of the world founded on the macrocosm and the microcosm, on sympathy and antipathy and on natural magic. This world system with its myriad analogies which were to be discovered through chemical laboratory analyses was anathema to them.

In short, the work of Paracelsus and his disciples was in the sixteenth century a frontal attack on both the natural philosophy and the medicine of the educational establishment. These Chemical Philosophers demanded educational reform to accommodate their views in the universities of Europe. The Galenists and the Aristotelians were further placed on the defensive by the insistence of the chemists that the ancient authorities had been heathens while they, in turn, were seeking a union of Christianity with the study of both man and nature. We now know the importance of the work of Copernicus and its implications, but to a scholar living in 1600 the Chemical Philosophy may well have posed a greater threat to tradition. And if this is true I think there is little doubt that we must reconstruct the chemical system of that period and follow the chemical debates to understand the origins of modern science. The study of the establishment of a heliocentric cosmos alone is simply insufficient.

Here we cannot discuss the Paracelsian debates in detail for lack of time.[8] The views of Paracelsus were not well known during his lifetime due probably to the fact that he had published so little while he was alive. It was not until the 1560s that his disciples began to publish these works — first individually, then in collected volumes, and finally in the ten volume *Opera* of Huser (1589-1591) which has served as the basis for all subsequent editions down to our own century. As early as 1572-74 Thomas Erastus (1524-1583) published a detailed critique of the Paracelsian position in which he attacked the chemical explanation of the Creation,

[8] Debus, *Chemical Philosophy*, 1, pp. 127-204.

the three Paracelsian principles, the use of chemically prepared medicines, and the Paracelsian reliance on the macrocosm-microcosm analogy. Rather, he praised the Aristotelian elements and the Galenic humoral explanation of disease. A learned professor of both medicine and theology, Erastus taught at both Heidelberg and Basel. He clearly upheld the primacy of Galen in medicine and Aristotle in natural philosophy. As for chemistry, he considered it at best a subject useful for the preparation of a very limited number of medicines.

In France the debate was at first a practical one centered on the introduction of chemically prepared medicines.[9] A work praising the value of antimony as a purge in 1564 led to a swift reaction by the Parisian Medical Faculty whose members proscribed the internal use of this mineral in 1566. From there the debate spread to the use of all chemicals in medicine and it took a century before antimony and its compounds were accepted by the Parisian physicians.

The reaction to the use of antimony and the work of Erastus indicate that from the start there were two levels to this debate: the first relating to the competing philosophies and the medical systems of the ancient authorities and the chemists, the second relating to the *materia medica*. Those who sought compromise such as Guinter von Andernach held to Galenic physiology, but praised the new chemical medicines (1571).[10] These strands of conflict continued to dominate scientific and medical debates for the next century. In France the defense of chemical medicine by the royal physician, Joseph Duchesne (1603)[11] led to an acrid pamphlet war between the chemists and the conservative members of the Medical Faculty. One immediate casualty was Theodore Turquet de Mayerne who had defended Duchesne and for this sin was ostracized by the members of the Faculty. This led to Mayerne's departure for London where he became the First Physician to the King and led the drive for the inclusion of chemicals in the first national pharmacopoeia, the *Pharmacopoeia Londinensis* of 1618.[12] In the course of the following decades the new chemicals — particularly the metallic and mineral compounds — became increasingly popular. The first appointment of a chemical physician to a professorial chair in a European university was Johannes Hartmann at Marburg in 1609, but by the end of the century there were chairs in chemistry in the medical faculties of most European universities.[13]

[9] *Ibid.*, pp. 145-82. The debate is discussed in considerably more detail in ALLEN G. DEBUS, *The French Paracelsians: The Chemical Challenge to Medical and Scientific Tradition in Early Modern France* (Cambridge: Cambridge University Press, 1991).

[10] J. GUINTERIUS [Guinter] VON ANDERNACH, *De medicina veteri et nova tum cognoscenda, tum faciunda commentarij duo* (2 vols., Basel: Henricpetrina, 1571).

[11] JOSEPH DUCHESNE [Quercetanus], *Liber de priscorum philosophorum verae medicinae materia, praeparationis modo, atque in curandis morbis, praestantia ...* (1603; I have used the 1613 edition published in Leipzig by Thom. Schürer and Barthol. Voight).

[12] Royal College of Physicians, *Pharmacopoeia Londinensis of 1618 Reproduced in Facsimile with a Historical Introduction by George Urdang* (Madison: University of Wisconsin Press, 1944).

[13] On Hartmann see BRUCE T. MORAN, *Chemical Pharmacy Enters the University: Johannes Hartmann and the Didactic Care of 'Chymiatria' in the Early Seventeenth Century* (Madison: American Institute of the History of Pharmacy, 1991). For a more general overview see ALLEN G. DEBUS, «Chemistry and the Universities of the Seventeenth Century», *Academiae Analecta: Klasse der Wetenschappen, 48* (1986), 13-33.

The seventeenth century acceptance of an essentially pharmaceutical chemistry was not the original goal of those Paracelsians who had sought to overturn the total philosophy of the ancients. During the course of the seventeenth century the chemical physiology of the iatrochemists was to become a major medical sect, but the chemical philosophy was never to become the dominant school of natural philosophy. If we are to go beyond pharmaceutical and medical questions we must seek a different locus of debate and here we may turn to the work of Robert Fludd (1574-1637).[14] Although he was a respected court physician and a member of the Royal College of Physicians, Fludd had little interest in practical pharmacy. His concern was with the establishment of a new philosophy based on a proper — and for him a thoroughly Christian and chemical — interpretation of the macrocosm and the microcosm.

Fludd had been convinced of the truth of the mystical Hermetic world view as a student at Oxford in the 1590s and he had decided then to prepare a monumental work on the great and the small worlds. However, little came of these plans for well over twenty years and he first published a short "apology" for the Rosicrucians in 1616. The first volume of his work on the macrocosm appeared the following year. Here he described the Creation as a chemical separation and he described the harmonic arrangement of the heavens. This was a subject of great interest to Johannes Kepler who was then completing his *Harmonices mundi*. Kepler paused to write a short appendix as a reply to Fludd and here as in later works he made the point that Fludd and other Hermeticists forced their data to fit preconceived views on cosmological harmonies. He, on the other hand, revised his theories to correspond to his data. This for Kepler was the true difference between a scientist and an alchemist/hermeticist. Kepler's reply surely did not convince Fludd, and a series of statements and answers were published over the next five years until Kepler finally ceased replying to his adversary. Kepler surely was not a total "modern" as any study of his views on heavenly harmonies will ascertain. However, the Kepler-Fludd exchange is of considerable interest since it deals with the proper role of mathematics in the interpretation of scientific data.

No less interesting is the debate between Fludd and Marin Mersenne. Fludd surely stood in the vanguard of those of the early seventeenth century who sought a replacement for the Aristotelian-Galenic world view. In contrast with others, his answer was a mystical-alchemical cosmology based on a mix of the *Corpus Hermeticum*, alchemy, and experimental evidence, and this was understandably anathema to Mersenne and his friends. Fludd believed that the world had been formed by a divine alchemical separation and that chemistry is the true key to both Nature and supernature. For Mersenne this was clearly heretical and in his *La verite des sciences*

[14] Over the past three decades there has developed an extensive literature on Fludd. I have summarized this to the mid-1970s in my *Chemical Philosophy*, 1, pp. 205-93 and in my introduction to my edition of Robert Fludd's *Philosophical Key* (New York: Science History Publications, 1979). Joscelyn Godwin has prepared a useful and well illustrated work in his *Robert Fludd: Hermetic philosopher and surveyor of two worlds* (London: Thames and Hudson, 1979) and more recently William H. Huffman has offered much new biographical information in *Robert Fludd and the end of the Renaissance* (London and New York: Routledge, 1988).

(1623)[15] he dismissed the broad claims of the chemists and argued that mathematics is the key to a new science. Mersenne felt that chemists should confine themselves to making medicines rather than dabbling in heretical interpretations of *Genesis*.

In 1628 Mersenne sent a set of Fludd's publications to his friend, Pierre Gassendi, with the request that he prepare an answer to them. Along with these works he enclosed a copy of William Harvey's recently published *De motu cordis* (1628) describing the circulation of the blood.[16] To Mersenne Harvey's work reflected Fludd's views on the macro-microcosmic circulation of the spirit of life. Gassendi dutifully wrote a rather detailed reply to Fludd in the course of which he rejected both the views of Fludd and Harvey on the cardiovascular system. Fludd then replied to Gassendi noting that Harvey was correct. The Galenic system that Gassendi supported required pores in the intraventricular septum of the heart. Fludd argued that these did not exist and he knew this for a fact since he had witnessed Harvey's attempt to find them on numerous occasions in his dissections. It was thus on observational evidence that Fludd supported Harvey in his own exchange with Gassendi.

There are those who would dismiss Fludd as not being in the mainstream of science. But in their rejection of Fludd's call for a new mystical chemical philosophy, Kepler, Mersenne and Gassendi had discussed subjects central to the establishment of a new science: the role of mathematics in the interpretation of data, the relative merits of mathematics versus chemistry as a key to a new science, and the place of observational and experimental evidence as opposed to tradition. I believe that debates such as these are essential for our understanding of the complex nature of early seventeenth-century science.

If it has been customary for historians of science to concentrate on the steps leading to the establishment of the Copernican system in the seventeenth century, it has also been customary to discuss the search for a new scientific methodology. Here the main figures have always been Francis Bacon and René Descartes. But if their work is integral to the rise of a "new philosophy", we may also turn to the largely neglected chemical tradition and the work of Jean Baptiste van Helmont (1580-1644). Published posthumously in 1648,[17] the collected works of van Helmont seemed to many of his contemporaries to offer an updated chemical philosophy largely devoid of the mystical extremes of earlier Paracelsians. He openly attacked specific views of Paracelsus, among them the concept of a microcosm containing within it all the things of the great world. Still, he admitted that there were enough

[15] Reprinted at Stuttgart/Bad Cannstatt: Friedrich Fromman Verlag, 1969.

[16] On the relation of Fludd to Harvey and the problem of the circulation of the blood see Allen G. Debus, «Robert Fludd and the Circulation of the blood», *Journal of the History of Medicine and Allied Sciences*, 16 (1961), 374-93 and «Harvey and Fludd: The Irrational Factor in the Rational Science of the Seventeenth Century», *Journal of the History of Biology*, 3 (1970), 81-105.

[17] The standard edition of the works is the first edition, the *Ortus medicinae* of 1648 which was reprinted at Brussels by Culture et Civilisation, 1966. I have discussed van Helmont's work in my *Chemical Philosophy*, 2, pp. 295-370. Walter Pagel's life-long interest in van Helmont culminated in his *Joan Baptista Van Helmont: reformer of science and medicine* (Cambridge: Cambridge University Press, 1982).

similarities between man and nature as a whole to make such comparisons valid. Like the earlier Paracelsians, van Helmont was particularly interested in medicine and for him chemistry was the true basis for the study of both nature and man. He wrote

> I praise my bountiful God, who hath called me into the Art of the fire, out of the dregs of other professions. For truly, Chymistry, hath its principles not gotten by discourses, but those which are known by nature, and evident by the fire: and it prepares the understanding to pierce the secrets of nature, and causeth a further searching out in nature, than all other Sciences being put together ...[18]

Van Helmont was convinced that fresh observations and laboratory experience were necessary in the training of students. Only in this way would it be possible to "destroy the whole natural Phylosophy of the Antients, and to make new the Doctrines of the Schooles of Natural Phylosophy".[19] To this end van Helmont outlined a seven year program of education in which students would learn first a group of fundamental subjects, and only then be initiated into the wonders of chemistry. Such a student, returning from such a school, would be a marvel since he would be so much above "the Phylosophers of the Universities and the vain reasoning of the Schooles".[20]

It would be incorrect to think that van Helmont believed that Scriptural evidence played no part in establishing scientific truth. Indeed, he relied on the first chapter of *Genesis* for his rejection of the four Aristotelian elements. However, he, no less than his contemporary, Galileo, rejected theology and theological training as appropriate for the sciences. In a debate with the Jesuit, Roberti, regarding the weapon salve cure in 1621, van Helmont wrote that

> ... Nature ... called not Divines for to be her Interpreters: but desired Physitians only for her Sons; and indeed, such only, who being instructed by the Art of the Fire, doe examine the Properties of things ... Certainly we also, who are the only faithful Interpreters of Nature, do by the same helps draw forth the Properties of things from Darkness into Light.[21]

It is no less interesting to note that like Galileo, van Helmont was tried and jailed by the Inquisition for his views.[22]

Van Helmont called his program a "nova Philosophia" and for many mid-century reformers this version of the Chemical Philosophy was the true "new philosophy". Walter Charleton (1620-1701) wrote three works in 1650 alone praising the work of the Belgian chemist-physician. And much of Robert Boyle's (1627-1691)

[18] VAN HELMONT, *Ortus medicinae* (1966), p. 463; from the «Pharmacopolium ac dispensatorium modernorum»: sect. 32). I have used the English translation of JOHN CHANDLER, *Oriatrike or Physick Refined* ... (London: Lodowick Loyd, 1662), p. 462.

[19] VAN HELMONT, «Promissa authoris», *Ortus medicinae*, p. 6; *Oriatrike*, p. 1.

[20] VAN HELMONT, «Physica Aristotelis et Galeni ignara» (sects. 9-11), *Ortus medicinae*, pp. 49-50; *Oriatrike*, p. 45.

[21] VAN HELMONT, «De magnetica» (sect. 8), *Ortus medicinae*, p. 750; *Oriatrike*, p. 761.

[22] The subject of van Helmont's persecution is currently being investigated by Robert Halleux. I have summarized the earlier literature in *my Chemical Philosophy*, 2, pp. 308-11.

early work reflects that of van Helmont. "I must here confess to you once for all, that ... I have not seen cause to disregard many things he delivers as matters of fact, provided they be rightly understood ...".[23] In *The Sceptical Chymist*, first published in 1661 although written in abstracted form nearly a decade earlier, Boyle demolished the Aristotelian elements and criticized the Paracelsian *tria prima* on the basis of analytical evidence he lifted directly from the Helmontian opera. And again, using the work of van Helmont, he carefully considered the evidence that water might be the basic element from which all material things are made. The influence of van Helmont on Boyle, Charleton and many others in the third quarter of the seventeenth century points to a continuing influence and broad appeal of Paracelsian thought during the most crucial period of the Scientific Revolution. We know now that even Isaac Newton read van Helmont with care and took notes on Helmont's concept of an inherent motive power of living things for which he coined the word *Blast*. In his discussion van Helmont considered, and then rejected, the possibility that there might be an equal and opposed reaction to any given action. For van Helmont this was a Galenic position, but it was to become Newton's Third Law of Motion.[24]

Nor did van Helmont's educational reform plans go unnoticed. A number of mid-century chemists turned to the Chemical Philosophy as a basis for a new educational system based on a proper understanding of the Book of Divine Revelation, Holy Scripture, and the Book of Nature. In 1654 John Webster said that such a program was needed so that future ministers would not be led astray by the heathenish writings of the Greek philosophers.[25] He thought that Robert Fludd might be followed for a Christian and an experimental approach to nature, but he literally plagiarized van Helmont's praise of chemistry as a mean of reaching God's truth in his Creation. Webster's call for curricular reform at Oxford and Cambridge Universities was rejected by the Oxford dons, John Wilkins and Seth Ward, who like Mersenne nearly thirty years earlier, sought a more mathematically based investigation of nature. Indeed, Wilkins and Ward argued that the traditional curriculum was far more valid than that of the Chemical Philosophers proposed by John Webster. And when Thomas Hall, a diehard Aristotelian, reviewed the debate, he felt that the position taken by Wilkins and Ward was far more acceptable than that of Webster. In this case we can not speak simply of a debate between ancients and moderns, but rather of a chemical philosopher whose views were opposed to those of both mechanists and Aristotelians.

The work of van Helmont had given a new lease of life to the Chemical Philosophy, but by the 1690s this debate was pictured in terms of ancients versus

[23] Robert Boyle, «... Usefulness of Experimental philosophy» (Part II, Sect. 1) in *The Works of the Honourable Robert Boyle* (6 vols., London: J. and F. Rivington et al., 1772), 2, p. 149.

[24] ALLEN G. DEBUS, «Van Helmont and Newton's Third Law», in *Paracelsus, Werk und Wirkung. Festgabe für Kurt Goldammer zum 60. Geburtstag*, edited by Sepp Domandl, *Salzburger Beiträge zur Paracelsusforschung, 13* (Vienna: Verband der wissenschaftlichen Gesellschaften Osterreichs Verlag, 1975), pp. 45-52.

[25] The texts of John Webster, John Wilkins, Seth Ward, and Thomas Hall are reproduced with an introduction by ALLEN G. DEBUS, *Science and Education in the Seventeenth Century. The Webster-Ward Debate* (London: Macdonald; New York: American Elsevier, 1970).

moderns as many texts would present the debate today. But what had happened to the Chemical Philosophy? In some cases we can witness a real conversion of scientists. Between 1650 and 1654 Walter Charleton changed from being a militant Helmontian to being a disciple of Copernicus, Gilbert, Mersenne and Descartes.[26] And, having read Gassendi, he sought to explain natural phenomena in terms of atoms. Robert Boyle also became converted to this corpuscular philosophy during the 1650s and his later work is characterized less by an adherence to an earlier medically oriented chemistry than it is by an effort to explain natural phenomena in terms of the size, shape and motion of particles.[27] His more youthful Helmontian phase is frequently neglected in favor of his later interest in the mechanical philosophy. And only in recent years have Newton's extensive chemical and alchemical texts been examined both in the light of contemporary chemical interests and in their relation to his work on the physics of motion and the aether. R. S. Westfall has noted Newton's union of the Hermetic and the mechanical traditions and B. J. Dobbs is making a thorough investigation of his alchemical manuscripts.[28] But these connections with an earlier mystical chemistry were largely forgotten or ignored by the philosophes of the eighteenth century.

It has been customary to picture the late seventeenth century triumph of a mechanical, non-vitalistic, science to the fact that it was a better science than the Aristotelian science it replaced. It is as if there were a Gresham's Law of science in which a better science displaces a lesser science. More recently — with a swing of the intellectual pendulum — it has been suggested that the intrinsic value of the new mathematical physics had little to do with the acceptance of the work of Newton. The extreme example is that of Margaret Jacob who has written that "Historians of science have often presumed that the new mechanical philosophy triumphed in England simply because it offered the most plausible explanation of nature".[29] Jacob however, disagrees since she finds the triumph of Newtonianism to be in

> its usefulness to the intellectual leaders of the Anglican Church as underpinning for their vision of what they liked to call the 'world politick'. The ordered, providentially guided, mathematically regulated universe of Newton gave [them] a model for a stable and prosperous polity, ruled by the self-interest of men.

[26] Nina Rattner Gelbart, «The Intellectual Development of Walter Charleton», *Ambix*, *18* (1971), 149-68.

[27] I have discussed Boyle's Helmontian phase in my *Chemical Philosophy*, *2*, pp. 473-84. See also the important recent study of Michael Hunter, «Alchemy, magic and moralism in the thought of Robert Boyle», *British Journal of the History of Science*, *23* (1990), 387-410.

[28] Richard S. Westfall, «Newton and the Hermetic Tradition», in Allen G. Debus, ed., *Science, Medicine and Society in the Renaissance: Essays to honor Walter Pagel* (2 vols., New York: Science History Publications, 1972), *2*, pp. 183-98 (195). See also Westfall's *Never at Rest: A Biography of Isaac Newton* (Cambridge, London, New York: Cambridge University Press, 1980). On the influence of alchemical thought on Newton see the many papers of Betty Jo Teeter Dobbs, but especially her *The Foundations of Newton's Alchemy or "The Hunting of the Greene Lyon"* (Cambridge, London, New York, Melbourne: Cambridge University Press, 1975).

[29] Margaret C. Jacob, *The Newtonians and the English Revolution 1689-1720* (Ithaca: Cornell University Press, 1976), pp. 16-17.

Surely the new scientific academies in London (1662) and Paris (1663) contributed to the overwhelming acceptance of a mathematically/mechanically interpreted world. Those chosen as members of these new societies formed a new scientific establishment. It was to be expected that they would reject Aristotelians for membership, but Paracelsians fared little better. In the accounts of the earliest meetings leading to the Royal Society of London we are told that their discussions avoided all reference to religion and politics.[30] But in England the chemists were generally committed to Puritanical or even non-conformist religious views — views that were favored by the factions opposed to the King and the royalist party. In France, a Roman Catholic country, the Paracelsians and the Helmontians also were for the most part Protestants. When Louis XIV revoked the Edict of Nantes in 1685, many were forced to abjure their religious beliefs or flee the country.[31]

There may seem to be little here that conflicts with familiar interpretations. For some the real issue is the debate between the Aristotelians and the Mechanists while for others the main thread of the development is to be found in the growth of rationality with a corresponding decline of a religious-mystical world view. But whether we concentrate on the decline of the ancient authorities or the so-called irrational thought of the mystics, the result remains a growth of a rational-mechanist world view. However, the story is surely more complex than this. The Chemical Philosophy that we have sketched here presents us with a spectrum ranging from a total macrocosmic-microcosmic universe to the practice of pharmacy.

We have already spoken of the general acceptance of chemically prepared remedies in the course of the seventeenth century with the concurrent establishment of chairs in chemistry in the medical faculties of most European medical schools by the end of that century. At the same time the influence of van Helmont had led to a new interest in a chemical understanding of bodily processes. This new chemical physiology or iatrochemistry strongly influenced many physicians in the late seventeenth and early eighteenth centuries. Franciscus de la Boë Sylvius and Thomas Willis became the leaders of this sect and their collected works continued to be published well into the new century[32] while the reviews in periodicals such as the *Journal des Sçavans* attest to the often sharp medical debates between this new brand of chemical physicians and those who sought to establish a mechanistic medicine. In the universities of Europe then, chemistry remained primarily a medical subject.[33]

But the development of chemistry as an independent subject may also be

[30] The account of John Wallis is quoted at length by DOUGLAS MCKIE in »The Origins and the Foundation of the Royal Society of London«, *Notes and Records of the Royal Society of London*, 15 (1960), 1-37 (11-13). The original account is to be found in *A Defence of the Royal Society* ... (1678).

[31] On the religion of the French Paracelsians see my *French Paracelsians*, *passim*. Some idea of the impact of the Revocation of the Edict of Nantes on French Protestant physicians may be had by noting the appropriate entries in WILLIAM MUNK, *The Roll of the Royal College of Physicians of London* ..., vol. I, 1518 to 1700 (London: Published by the College, 1878).

[32] Editions of the work of Willis (Venice, 1720) and Sylvius (Paris, 1771) attest to the interest in their chemically based medicine until well into the eighteenth century.

[33] DEBUS, »Chemistry and the Universities in the Seventeenth Century«, note 13.

traced to Paracelsian roots. The phlogiston theory of Georg Ernst Stahl has been normally linked with the work of Johann Joachim Becher and his inflammable earth or *terra pinguis*. And although both Becher and Stahl were medical doctors, they both discussed chemistry primarily in terms of inorganic processes. As a result, the phlogiston chemistry of the mid-eighteenth century was in many ways different from the pharmaceutical and physiological processes taught in the medical schools.[34] A new school of vitalistic medicine at Montpellier rejected chemical explanations of physiological processes,[35] and as Christoph Meinel has recently shown, there was a gradual decline of medical chemistry in mid-century with the ascendancy of mechanistic medicine.[36] As a result, the new phlogiston chemistry developed largely as an inorganic subject. It was this non-medical chemistry that Lavoisier reacted against in the third quarter of the eighteenth century.

Let me make one additional point. I have mentioned earlier that in the seventeenth century there was a rapid decline in interest in the macrocosm-microcosm system with its myriad analogies and sympathetic forces ... a system that had been favored by most of the earlier Paracelsians. I have also pointed out that those chemical philosophers who believed in such a world view were excluded from the newly formed scientific academies. However, such exclusion did not mean that they no longer existed. The large volume of alchemical publications printed in all parts of Europe in the late seventeenth and throughout the eighteenth centuries shows that there was a continued fascination with this subject. Nor need we concern ourselves only with obscure figures when we deal with the latter century. Both Hermann Boerhaave and Georg Ernst Stahl devoted much time and effort to their study of transmutation. Here we have the case of two very different figures, both professors of medicine and chemistry, who saw no reason to reject the possibility of transmutation, and who both looked on the alchemical works ascribed to Isaac Hollandus as being of special value.[37]

One characteristic of late eighteenth century science is the reaction against the long dominant mechanistic world view as seen in the work of Mesmer, Hahnemann, and the *naturphilosophie* of Central Europe. The background to these developments has not yet been worked out in satisfactory detail, but I believe that when it is, we will find that it is linked to the persistent interest in a non-mechanistic chemical world view that continued throughout the century outside of the scientific acade-

[34] DEBUS, *Chemical Philosophy*, 2, 458-69. There is a growing interest in the background to the Chemical Revolution of the eighteenth century. Of special interest is FERDINANDO ABBRI, *Elementi, Principi e Particelle: le teorie chimiche da Paracelso a Stahl* (Torino: Loescher Editore, 1980) and his shorter paper, «Traduzioni chimiche nel settecento» in *Atti del I° Convegno di Storia della Chimica*, Paola Antonaotti and Luigi Cerruti, eds. (Torino: A cura del Centro Stampa Università, 1986), pp. 1-23.

[35] ELIZABETH HAIGH, *Xavier Bichat and the Medical Theory of the Eighteenth Century*, *Medical History*, Supplement No. 4 (1984). I have discussed the relationship of Montpellier medicine to the older vitalism in my *French Paracelsians*, pp. 198-201.

[36] CHRISTOPH MEINEL, «Artibus Academicus Inserenda: Chemistry's Place in Eighteenth and Early Nineteenth Century Universities», *History of Universities*, 7 (1988), 89-115.

[37] See my discussion of Herman Boerhaave and Georg Ernst Stahl in *The French Paracelsians*, pp. 189-201.

mies. The enemies of Mesmer accused him of plagiarizing the works of Paracelsus.[38] Robert Fludd and van Helmont, while nineteenth century histories of homeopathy linked Hahnemann's work with that of Stahl and van Helmont.[39] Studies of *naturphilosophie* show this to be a movement drawing upon concepts from an earlier vitalistic and chemical interpretation of nature. Surely this is true of Schelling while Kant attacked the views of Bacon, Boyle and Newton whose work had led to a mechanistic world picture.

In the course of the past hour I have skimmed rapidly over an enormous subject. I have attempted to show that the traditional interpretation of the Scientific Revolution based on a gradual acceptance of a heliocentric world view from Copernicus to Newton is quite insufficient. I hope to have shown that in addition to the mechanical philosophers there were the chemists who sought to establish their own version of a new philosophy in the sixteenth and seventeenth centuries. In his recent award-winning book, *Revolution in Science*, I. Bernard Cohen commented that little attention has as yet been paid to failed revolutions.[40] The proposed revolution of the chemical philosophers would surely be one of these for him. But the chemists clearly were looked upon as rivals and as a real threat to those who looked to a new science based on mathematics rather than chemistry — figures such as Kepler, Mersenne and Gassendi. As we have seen, this debate in the sciences continued through the seventeenth century, and in medicine well into the eighteenth century. I believe that a proper understanding of late eighteenth and early nineteenth century antimechanistic trends in the sciences will best be understood when we have unravelled the complex "underside" of eighteenth century science — that is, the persistent and continuing interest in vitalism, magic and alchemy.

As historians perhaps we should best return to the admonition by Herbert Butterfield that I quoted at the beginning, that the historian "is back in his proper place when he takes us away from simple and absolute judgments and by returning to the historical context entangles everything up again". If we as historians follow Butterfield's lead, we will find that we will have to pay more attention to views that were of real concern in the past, but which no longer form part of our present day science. Part of our task is — and always will be — to work out in detail the technical and internalist development of the sciences. This will always form an essential core of our histories. But such technical material must be set in a larger context that includes the intellectual, religious and social currents of the period we are inte-

[38] ALLEN G. DEBUS, «The Paracelsians in eighteenth-century France: A Renaissance Tradition in the Age of the Enlightenment», in *Transformation and Tradition in the Sciences: Essays in Honor of I.Bernard Cohen*, Everett Mendelsohn, ed. (Cambridge, London, New York, New Rochelle, Melbourne, Sydney: Cambridge University Press, 1984), pp. 193-214 (206-208). I plan to make this the subject of a full scale study.

[39] As an example see A.Gerald Hull, «... A Brief Survey of the Progress and Present State of Homeopathia in Europe» in Rev. THOMAS R. EVEREST, *A Popular View of Homeopathy* ... from the Second London Edition (New York: William Radde, 1842), pp. 179-243.

[40] I. BERNARD COHEN, *Revolution in Science* (Cambridge, Massachusetts and London, England, 1985), pp. 31ff.

rested in. If we approach the Scientific Revolution in this way we will be forced to realize that the chemical philosophers are fully as important for our understanding of the debates of the sixteenth and seventeenth centuries as is the development of the study of local motion in that period. In short, I believe that Paracelsus is fully as important for our understanding of sixteenth century science as is Copernicus, and van Helmont should be studied with as much care as Galileo.