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CHAPTER I

Tradition and Reform

Few events in world history have been more momentous than the Scientific Revolution. The period between the mid-fifteenth and the end of the eighteenth centuries witnessed the growing cultural and political influence of Western Europe over all other parts of the globe. The new science and technology of the West was a crucial factor in this development, a fact recognized by most scholars at the time. Thus, Francis Bacon (1561–1626) observed in the *Novum organum* (1620) that

"it is well to observe the force and virtue and consequences of discoveries; and these are to be seen nowhere more conspicuously than in those three which were unknown to the ancients . . . ; namely, printing, gunpowder, and the magnet. For these three have changed the whole face and state of things throughout the world; the first in literature, the second in warfare, the third in navigation; whence have followed innumerable changes; insomuch that no empire, no sect, no star seems to have exerted greater power and influence in human affairs than these mechanical discoveries."

For Bacon these discoveries were Western in origin and relatively recent in date. He was neither the first nor the last to make such a statement, but there were few whose works were read more avidly by those who hoped to erect a new science in the seventeenth century.

But if the importance of the Scientific Revolution is readily admitted by all, the more we study its origins, the more unsure we become of its causes. In this volume we shall be concerned primarily with the two centuries from 1450 to 1650, the first date coinciding roughly with the beginning of the new humanistic interest in the classical scientific and medical texts and the second with the years just prior to the general acceptance of the mechanistic science of Descartes (1596–1650), Galileo (1564–1642), Borelli (1608–1679), Boyle (1627–1691), and Newton (1642–1727).

These two centuries present an almost bewildering maze of interests, and only rarely will an individual be found whose scientific methodology would prove to be fully acceptable to a modern scientist. Some of the scholars, whose work contributed to our modern scientific age, found magic, alchemy, and astrology no less stimulating than the new interest in mathematical abstraction, observation, and experiment. Today we find it easy – and necessary – to separate "science" from occult interests, but many then could not. And we cannot relegate this interest in a mystical world view to a few lesser figures forgotten today except by antiquarians. The writings of Isaac Newton and Johannes Kepler (1571–1630) reveal a genuine interest in transmutation and a search for universal harmonies no less than the work of Paracelsus (1493–1541), Robert Fludd (1574–1637), or John Dee (1527–1608). For the most part it has been traditional among historians of science to view their subject by hindsight, that is, to ignore those aspects of an earlier natural philosophy that no longer have a place in our scientific world. However, if we do this we cannot hope to reach any contextual understanding of the period. It will thus be our aim to treat this period in its own terms rather than ours. As we proceed we shall find that controversies over natural magic and the truth of the macrocosm – microcosm analogy were then as important as the better-remembered debates over the acceptance of the heliocentric system or the circulation of the blood.

Renaissance Science and Education

The very words "Renaissance" and "humanism" have been employed with so many connotations that there is little hope of satisfying any two scholars with a single definition. There is no need to try to do so here. To be sure, the Renaissance did involve a kind of "rebirth" of knowledge – no less than it did a rebirth of art and literature. And it was surely the period of the development of a new science. But having granted this, it is necessary to be careful to avoid simplification. The new love of nature expressed by Petrarch (d. c. 1374) and other fourteenth-century humanists had more than one effect. We readily accept that it was instrumental in the rise of a new observational study of natural phenomena, but we also find that Petrarch and later humanists deeply distrusted the traditional scholastic emphasis on philosophy and the sciences. The rhetoric and history they preferred was a conscious reply to the more technical "Aristotelian" studies that had long been the mainstay of the medieval university. The humanists sought the moral improvement of man rather than the logic and scholastic disputations characteristic of traditional higher learning.

These shifting values were to result in a new interest in educational problems. Fourteenth- and fifteenth-century reform programs were to be directed toward elementary education rather than the universities. The humanist educator Vittorino da Feltre (1378–1446) established a new school where students were urged to excel at sports and to learn military exercises. In classrooms they studied rhetoric, music, geography, and history – and, taking their examples from the ancients, they were taught to value both moral principles and political action above the basic principles of the trivium (grammar, rhetoric, and logic) or the study of traditional philosophical and scientific subjects.

Many of the most renowned humanist scholars were to be affected by this movement in educational reform. The result may be clearly seen in the work of Erasmus (1466–1536). He thought it enough for a student to learn of nature through his normal course of study in the reading of the ancient literary authors. Mathematics was not to him of much importance for an educated man. And Juan Luis Vives (1492–1540), surely the best known of all Renaissance educators, agreed fully when he argued against the study of mathematics that it tended to "withdraw the mind from practical concerns of life" and rendered it "less fit to fuse concrete and mundane realities."

But can we then say that the universities remained the centers of scientific training? For the most part they did, but there was an ever-increasing number of scholars both in medicine and the sciences who rejected the overwhelming conservatism of many – and perhaps most – of the institutions of higher learning. Peter Ramus (1515–1572) recalled his own academic training with despair:

"After having devoted three years and six months to scholastic philosophy, according to the rules of our university: after having read, discussed, and meditated on the various treatises of the *Organon* (for of all the books of Aristotle those especially which treated of dialectic were read and re-read during the course of three years); even after, I say, having put in all that time, reckoning up the years completely occupied by the study of the scholastic arts, I sought to learn to what end I could, as a consequence, apply the knowledge I had acquired wih so much toil and fatigue. I soon perceived that all this dialectic had not rendered me more learned in history and the knowledge of antiquity, nor more skillful in eloquence, nor a better poet, not wiser in anything. Ah, what a stupefaction, what a grief! How did I deplore the misfortune of my destiny, the barrenness of a mind that after so much labor could not gather or even perceive the fruits of that wisdom which was alleged to be found so abundantly in the dialectic of Aristotle!"

Ramus was not alone in his frustration – and his complaints were not without grounds. Paris, for example, was acknowledged as a stronghold of Galenic medicine in the sixteenth and seventeenth centuries whereas in England both the Elizabethan statutes for Cambridge (1570) and also the Laudian code for Oxford (1636) maintained the official authority of the ancients. Nor were the early professional societies necessarily better. The London College of Physicians looked on innovation with distrust. Thus, when in 1559 Dr. John Geynes dared to suggest that Galen (129/130–199/200 A.D.) might not be infallible, the reaction was immediate and severe. The good doctor was forced to sign a recantation before being received again into the company of his colleagues.

The conservatism seen in many major universities in the sixteenth and seventeenth centuries may be partially balanced by a critical tradition that had been applied to the ancient scientific texts at Oxford and Paris in the fourteenth century. This work, associated with scholasticism, was to prove particularly beneficial to the study of the physics of motion. As a scholarly tradition it was still in evidence at Padua and other northern Italian universities in the sixteenth century. For many, however, scientific criticism was a curious kind of humanistic game in which the scholar was to be commended for having eliminated the vulgar annotations and emendations of medieval origin that marred the texts of antiquity. His goal was textual purity rather than scientific truth.

In short, the educational climate in the early Renaissance was of questionable value for the development of the sciences. University training in this period may be characterized for the most part as conservative. As for the reform of primary education accomplished in the fourteenth and fifteenth centuries, this was openly antiscientific.

Humanism and Classical Literature

Dedication to the ancients is a familiar characteristic of Renaissance humanism. The search for new classical texts was intense in the fifteenth century, and each new discovery was hailed as a major achievement. No account is better known than that of Jacopo Angelo (fl. c. 1406). His ship sank as he was returning from a voyage to Constantinople made in search of manuscripts, but he managed to save his greatest discovery, a copy of the *Geography* of Ptolemy hitherto unknown in the West. Not long after this, in 1417, Poggio Bracciolini (1380–1459) discovered what was later to be recognized as the only copy of Lucretius's (c. 99–55 B.C.) *De rerum natura* to have survived from antiquity. This was to become a major stimulus for

the revived interest in atomism two centuries later. And, just nine years after the recovery of Lucretius, Guarino da Verona (1370–1460) found a manuscript of the encyclopedic treatise on medicine by the second-century author, Celsus. This work, *De medicina,* was to exert a great influence, an influence due perhaps less to its medical content than to its language and style. This was the only major medical work to have survived from the best period of Latin prose and it was to be mined by medical humanists who sought proper Latin terminology and phrasing.

The search for new texts – and new translations – resulted in a new awareness of the importance of Greek. To be sure, Roger Bacon (c. 1214–1294) had already underscored this need in the thirteenth century, but the situation had not materially improved a century later. At that time Petrarch had lamented his own inadequate knowledge of this language. In fact he was not alone. Few Western scholars were able to use Greek until the teacher Manuel Chrysolorus (d. 1415) arrived in Italy with the Byzantine Emperor Manuel Paleologus in 1396. But helpful though Chrysolorus was, much greater enthusiasm was stirred by another Byzantine, Gemistos Plethon, on his arrival at the Council of Florence in 1439. The Greek revival was to affect all scholarly fields in the course of the fifteenth century. In medicine the humanist Thomas Linacre (c. 1460–1524) prepared Latin translations of Proclus (410–485) and of individual works of Galen. Significant though this was, his plans – only partially fulfilled – were actually far more grandiose. He projected a Latin translation of the complete works of Galen – and, with a group of scholars, a Latin translation of the complete works of Aristotle as well. Hardly less industrious was Johannes Guinter of Andernach (1505–1574), whose translations from Galen place him in the front rank of medical humanists. As professor of medicine at Paris, Guinter became one of the most prominent teachers of the young Andreas Vesalius (1514–1564).

This quest for truth in the search for accurate manuscripts was not confined solely to the study of the ancient physicians. Georg von Peuerbach (1423–1461) recognized the need for an accurate manuscript of Ptolemy's *Almagest* while writing his textbook, the *Theoricae novae planetarum.* But Peuerbach died while he was in the process of planning a journey to Italy to accomplish this end. His pupil, Johann Müller (Regiomontanus) (1436–1476) completed his master's journey and published an *Epitome* of the *Almagest.*

But Renaissance humanism cannot simply be reduced to the recovery of a pure Aristotle, Ptolemy, or Galen. No less influential on the development of modern science – and certainly part of the same humanistic move-

ment – was the revival of the neo-Platonic, cabalistic, and Hermetic texts of late antiquity. So important did these seem to be that Cosimo de' Medici insisted that Marsilio Ficino (1433–1499) translate the recently discovered *Corpus hermeticum* (c. 1460) before turning to Plato or Plotinus. These mystical and religious works – to be discussed later in more detail – seemed to justify the pursuit of natural magic, a subject of great popularity among the savants of the sixteenth and seventeenth centuries. Included in this tradition was the call for a new investigation of nature through fresh observational evidence.

Coincidentally, this search for the pure and original texts of antiquity occurred when a new means existed for disseminating this knowledge, the printing press. It is interesting that the earliest printed book from Western Europe dates from 1447, at the very beginning of our period. For the first time it became possible to produce standard texts for scholars at a moderate price. In the scientific and medical fields these incunabula were for the most part printings of the old medieval scholastic texts scorned by the humanists. Thus the first version of Ptolemy's *Almagest* to be printed was the old medieval translation (1515). A new Latin translation appeared next (1528) – and finally the Greek text (1538), just five years prior to the *De revolutionibus orbium* of Copernicus. Galen and Aristotle were to proceed through the same stages.

The Growth of the Vernacular

Latin and Greek were surely the primary keys to the world of the scholar, but the Renaissance world was also characterized by a rapid growth in the use of the vernacular languages in learned fields. This is seen most strikingly in the religious pamphlets of the Reformation, where the author had an immediate need to reach his audience. But the use of the vernacular also became increasingly important in science and medicine in the course of the sixteenth century. This may be ascribed partially to the conscious nationalistic pride seen in this period. It is a time when authors wrote openly of their love of their native land and of their own language. A second factor was the feeling on the part of many of the need for a decisive break with the past. This seems to be ever more evident after the second quarter of the sixteenth century.

Recent research indicates a rapid increase in the use of the vernacular in the medical texts of the late Middle Ages. This trend intensified in the sixteenth century when a medical pamphlet war divided the Galenists from the Paracelsian medical chemists. This debate had been brought to the uni-

versity level when Paracelsus lectured on medicine at Basel in his native Swiss-German in 1527. The medical establishment attacked him in force not only for the content of his lectures, but also for his choice of language. The latter was to remain a sore point among his followers for generations to come. Thus, the English Paracelsist Thomas Moffett (1553–1604) admitted – in Latin (1584) – that

"it is true that Paracelsus spoke often in German rather than Latin, but did not Hippocrates speak Greek? And why should they not both speak their native tongues? Is this worthy of reprehension in Paracelsus and to be passed over in Hippocrates, Galen and the other Greeks who spoke in their own language?"

The situation was not appreciably different in mathematics and the physical sciences. Galileo's publications in Italian remain classics of Italian literature today and in England numerous authors presented both popular and technical subjects in Tudor English. Of special interest is John Dee, who took it on himself to compose a preface to the first English translation of the *Elements of Geometry* by Euclid. Here he thought it necessary to explain that such a translation would pose no threat to the universities. Rather, he argued, many common folk might well for the first time be able "to finde out, and devise, new workes, straunge Engines, and Instrumentes: for sundry purposes in the Common Wealth or for private pleasure and for the better maintayninge of their owne estate." Similar apologies for the publication of scientific and medical texts in the vernacular are to be found in the other major modern languages from this period.

Observation and Experiment

Any general assessment of Renaissance science must include a discussion of a number of seeming paradoxes. A recurring theme in the sixteenth-century literature is the rejection of antiquity. But, as we have already noted, this rejection most commonly was directed at scholastic translations and commentaries. Some scholars did call for a completely new natural philosophy and medicine, but many adhered to the ancient philosophy – provided that they were assured that their texts were pure and unadulterated. There were those such as William Harvey (1578–1657), who openly praised the Aristotelian heritage. Others – and here Robert Fludd is a good example – attacked the ancients viciously while integrating many ancient concepts in their own work.

Also characteristic of the period was a growing reliance on observation

and a gradual move toward our understanding of experiment as a carefully planned – and repeatable – test of theory. Older classics of observational science and method were recognized and praised by Renaissance scholars, who saw in them a model to be emulated. Thus many who rejected Aristotle's physics pointed to his work on animals as a text of major importance. Because of his use of observational evidence, Archimedes (287–212 B.C.) had great weight, whereas among medieval authors Roger Bacon, Peter Perigrinus (of Maricourt) (fl. c. 1270), and Witelo (Theodoric of Freiburg) (thirteenth century) were cited for their "experimental" studies.

Yet even though Roger Bacon and others might speak of a new use of observation as the basis for an understanding of the universe, it was far more customary to rely upon fabulous accounts related by Pliny the Elder (23–79 A.D.) or other ancient encyclopedists. Even the brilliant critique of the ancient physics of motion carried out at Oxford and Paris in the fourteenth century had been based more upon deductive reasoning and the rules of logic than upon the results of any new observational evidence.

The scientists of the sixteenth century did not immediately develop a modern understanding of the use of experiment, but there is evident in their work a more general recourse to observational evidence than existed before. Thus Bernardino Telesio (1509–1588) founded his own academy at Cosenza, which was dedicated to the study of natural philosophy. Rejecting Aristotle, whose work seemed to disagree with both Scripture and experience, he turned instead to the senses as a key to the study of nature. Of equal interest is John Dee, who numbered among his mathematical sciences *Archemastrie,* which "teacheth to bryng to actuall experience sensible, all worthy conclusions by all the Artes Mathematicall purposed. . . . And bycause it procedeth by *Experiences,* and searcheth forth the causes of Conclusions, them selues, in Experience, it is named of some *Scientia Experimentalis.* The *Experimentall Science.*" Here the word "experimental" may best be understood as "observational." The concept of the modern controlled experiment was not part of Dee's methodology.

Mathematics and Natural Phenomena

Surely no less important than the new appreciation of observational evidence was the development of quantification and the increasing reliance on mathematics as a tool. Plato had stressed the importance of mathematics, and the revived interest in his work did influence the sciences in this area. In our period Galileo stands as the key figure in this development. Viewing mathematics as the essential guide for the interpretation of nature, he

sought a new description of motion through the use of mathematical abstraction. In doing so Galileo was acutely aware that he was departing from the traditional Aristotelian search for causes.

Combined with the novel use of mathematics in natural philosophy, there were dramatic new developments within mathematics itself. The work of Tartaglia (1500–1557), Cardano (1501–1576), and Viète (1540–1603) in algebra did much to advance that subject in the sixteenth century – and tedious arithmetical calculations were greatly simplified through the invention of logarithms by Napier (1550–1617). And only slightly beyond our period comes the invention of the calculus by the independent efforts of Leibniz (1646–1716) and Newton. All these tools were quickly seized upon by contemporary scientists as aids to their work.

If one were to ask the reasons for this use of mathematics in the sixteenth century, one might arrive at a variety of answers. One would surely be the new availability of the work of Archimedes, the Greek author whose approach most closely approximated that of the new science. His texts had never been completely lost, but there is clear evidence of a new Archimedean influence in the mid-sixteenth century with a series of new editions of his work. Another factor of importance is the persistence of interest in the study of motion initiated by the fourteenth-century scholars at Oxford and Paris. There seems little doubt that Galileo was as a student the beneficiary of this tradition. A third factor was surely the Platonic, neo-Platonic, and Pythagorean revival. This influence often had a mystical flavor, but whatever its form, it was an important stimulus for many scientists of the period. And finally, one might point to the need for practical mathematics associated with the practical arts and technology.

Technology

It is rewarding to pause momentarily to examine this new interest in technology. While the extent of the relationship is open to debate, it is clear that at the very least those interested in warfare required mathematical studies in their use of cannon, and the navigator had to perform calculations to determine his position at sea. This was a period that witnessed impressive advances in instrumentation, ranging from practical astrolabes for the mariner to the massive astronomical instruments built by Tycho Brahe. The telescope, the microscope, the first effective thermometers, and a host of other tools were developed by artisans and scientists alike. Indeed, the scientists were taking an active interest in the work of the tradesmen for the first time. This may be interpreted partially as a revolt against the au-

thority of the ancients, as most ancient and medieval studies of nature were totally divorced from processes employed by workmen. The scholastic student of the medieval university agreed with the ancients and rarely left his libraries and study halls. In the Renaissance, however, we witness a great change. There may be few descriptions of the practical arts in the books of the fifteenth century, but handbooks of mining operations began to appear from the presses as early as 1510 and similar works relating to other fields appeared shortly thereafter.

In contrast to earlier periods the scientists and physicians now acknowledged openly that the scholar would do well to learn from the common man. Paracelsus advised his readers that

"not all things the physician must know are taught in the academies. Now and then he must turn to old women, to Tartars who are called gypsies, to itinerant magicians, to elderly country folk and many others who are frequently held in contempt. From them he will gather his knowledge since these people have more understanding of such things than all the high colleges."

And Galileo candidly began his epoch-making *Discourses and Demonstrations Concerning Two New Sciences* (1638) with the following statement:

"The constant activity which you Venetians display in your famous arsenal suggests to the studious mind a large field for investigation, especially that part of the work which involves mechanics; for in this department all types of instruments and machines are constantly being constructed by many artisans, among whom there must be some who, partly by inherited experience and partly by their own observations, have become highly expert and clever in explanation."

This list could be greatly amplified if we took into account the great mining treatises of Agricola (1494–1555) and Biringuccio (fl. c. 1540), the views of Francis Bacon on the practical purpose of science, and the stated practical goals of the early scientific societies. There is little doubt that some areas of science progressed because the contribution of artisans and scientists fostered the study of practical processes. Johann Rudolph Glauber (1604–1670) was so encouraged by the developments he had witnessed that he forecast the supremacy of Germany over all Western Europe if its rulers would only follow his plan outlined in the *Prosperity of Germany*. And yet, even if we grant this belated recognition of technology by the scientist, there was no appreciable feedback from the small scientific community to technology until well into the eighteenth century.

Mysticism and Science

A fourth ingredient in the formation of the new science – and a most unlikely one from our post-Newtonian vantage point – was the new Renaissance interest in a mystical approach to nature. Much of this may be attributed to the strong revival of interest in the Platonic, neo-Platonic, and Hermetic writings. It is instructive to note this influence first in mathematics and then in the widespread interest in natural magic.

From our point of view Renaissance mathematics had the effect of a double-edged sword. On the one hand, the new interest in mathematics furthered the development of a mathematical approach to nature and the internal development of geometry and algebra; on the other hand, the same interest resulted in occultist investigations of all kinds related to number mysticism. Renaissance cabbalistic studies encouraged a mystical numerological investigation of the Scriptures with the hope that far-reaching truths would be found. Similarly magic squares and harmonic ratios seemed to offer insight into nature and divinity. Even in antiquity this tendency was embodied in the Pythagorean tradition prior to the time of Plato. The latter's numerological speculations in the *Timaeus* were to continue to affect the world of learning throughout the Middle Ages, and with the revival of the texts of late antiquity in the fifteenth century the same themes were heard once again.

It is important not to try to separate the "mystical" and the "scientific" when they are both present in the work of a single author. To do so would be to distort the intellectual climate of the period. Of course it is not difficult to point to the mathematical laws governing planetary motions formulated by Kepler or the mathematical description of motion presented by Galileo. These were basic milestones in the development of modern science. But it should not be forgotten that Kepler sought to fit the orbits of the planets within a scheme based upon the regular solids, and Galileo was never to relax his adherence to circular motion for the planets. Both authors reached conclusions that were strongly influenced by their belief in the perfection of the heavens. Today we would call the first examples "scientific," the second not. But to force our distinction upon the seventeenth century is ahistorical.

Robert Fludd offers an excellent example of an Hermetic–chemical approach to mathematics. Few would have insisted more than he that mathematics was essential for any study of the universe. But Fludd would have added that the true mathematician should lift his sights high. His aim should be to show the divine harmonies of nature through the interrelation-

ship of circles, triangles, squares, and other figures. These would clearly indicate the connections of the great world to man. Fludd sought a new approach to nature and, like Kepler and Galileo, he hoped to use mathematics as a key, but for him quantification was something quite different than it was for the others. Fludd believed that the mathematician should use this tool to study the overall design of the universe. He should not – like Galileo – be concerned with lesser phenomena such as the motion of a falling object.

The case of mathematics is of special importance because of the significance of quantification in the rise of modern science, but the occult or mystical influence of late Hellenistic philosophy had a much deeper impact on sixteenth-century thought than this alone Implicit in neo-Platonism and the Christian traditions was the belief in a unity of nature, a unity that encompassed God and the angels at the one extreme and man and the terrestrial world at the other. Along with this was a continued belief in the truth of the macrocosm–microcosm relationship, the belief that man was created in the image of the great world, and that real correspondences do exist between man and the macrocosm.

The general acceptance of the macrocosm and the microcosm along with the great chain of being gave credence to the acceptance of correspondences existing everywhere between the celestial and sublunary worlds. In the ancient world such beliefs seemed to give a solid basis for astrology. It seemed reasonable to assume that stars should influence mankind here on earth. In the Renaissance many agreed, astral influences did indeed affect the earth and man. The Hermetic texts added a new ingredient to this world view. Largely on their basis man was now viewed as a favored link in the great chain of being. Partaking in Divine Grace, he was something more than the passive recipient of starry influences. And, as there is a general sympathy between all parts of the universe, man may affect supernature as well as be affected by it. This concept had immediate value in medicine through the doctrine of signatures. Here it was postulated that the true physician had the power successfully to seek out in the plant and mineral kingdoms those substances that correspond with the celestial bodies, and therefore ultimately with the Creator.

All this is closely related to the basis of Renaissance natural magic. The true physician of the Paracelsus or Ficino type was at the same time a magician who conceived nature to be a vital or magic force. Such a student of nature might learn to acquire natural powers not known to others and thus astonish the populace, even though these powers were known to be

God-given and available to all. Indeed, to many this seemed to be one of the most attractive aspects of magic. Thus, late in life, John Dee recalled his student days at Cambridge where he had prepared a mechanical flying scarab for a Trinity College performance of Aristophanes' *Peace,* "whereat was great wondering, and many vaine reportes spread abroad of the meanes how that was effected." Dee's scarab was in the tradition of Hellenistic mechanical marvels, but he was also well aware that true magic meant the observational study of the unexplained or occult forces of nature. Thus in his *Natural Magick* John Baptista Porta (1540–1615) had explained that magic is essentially the search for wisdom and that it seeks nothing else but the "survey of the whole course of nature." Still earlier Heinrich Cornelius Agrippa (c. 1486–1535) called this the most perfect knowledge of all, and Paracelsus equated it with nature itself and spoke of it in terms of a religious quest that would lead the seeker to a greater knowledge of his Creator.

For such men natural magic was far removed from the taint of necromancy. Rather, magic was closely associated with religion through the search for divine truths in created nature. Nevertheless, the scientist who was willing to accept the title of "magician" might well expose himself to danger. Again John Dee will serve as an example. Imprisoned early in life for his active interest in astrology, he was later to have his vast library destroyed by an angry mob. Appealing to his readers for sympathy, he asked whether they could really think him such a fool as "to forsake the light of heauenly Wisedome: and to lurke in the dungeon of the Prince of darknesse?" Despite the accusations that had been made, he held himself to be "innocent, in hand and hart: for trespacing either against the lawe of God, or Man, in any of my Studies of Exercises, Philosophicall, or Mathematicall."

In reality sixteenth-century natural magic was a new attempt to unify nature and religion. For the Hermeticists and the natural magicians the works of Aristotle were flawed by heretical concepts, and they were repeatedly to recall that church councils had condemned many of these Aristotelian errors. This being the case, why should Aristotle and Galen still be the basis of university teaching when there was another interpretation of nature through natural magic and occult philosophy – subjects whose very existence depended upon the sacred Scriptures? How could it be that any Christian should prefer the atheistic Aristotle to this new and pious doctrine? In truth, they argued, knowledge may be acquired by Divine Grace alone; either by some experience such as St. Augustine's divine illumina-

tion or else by means of experiment in which the adept might attain his end with the aid of divine revelation. The religious content of early-seventeenth-century Hermeticism is evident in the work of Thomas Tymme (d. 1620), who wrote (1612) that

"the Almighty Creator of the Heavens and the Earth . . . hath set before our eyes two most principal books: the one of nature, the other of his written Word . . . The wisdom of Natures book, men commonly call Natural Philosophy which serveth to allure to the contemplation of that great incomprehensible God, that wee might glorify him in the greatness of his work. For the ruled motions of the Orbes . . . the connection, agreement, force, virtue, and beauty of the Elements . . . are so many sundry natures and creatures in the world, are so many interpreters to teach us, that God is the efficient cause of them and that he is manifested in them, and by them, as their final cause to whom also they tend."

This was written to explain why he had prepared a book devoted to nature, the generation of the elements, and other essentially scientific topics. For an author such as Tymme science and the observation of nature were a form of divine service, a true link with divinity. In a sense natural research was a quest for God.

The student of Renaissance science must thus cope with more than the work of Copernicus and its consequences or the anatomical research leading to the discovery of the circulation of the blood. As for scientific method, the historian must concern himself with the new interest in mathematics and quantification all the while taking care not to divorce it from subjects as alien to modern science as the doctrine of signatures and natural magic. Indeed, our science today owes much to that search for a new synthesis of man, nature, and religion, which characterized the work of many scientists and physicians four centuries ago.

Renaissance science and medicine were deeply influenced by three figures of the sixteenth century and three others from antiquity. The first three were Nicholas Copernicus (1473–1543), Andreas Vesalius, and Philliptus Aureolus Theophrastus Bombastus von Hohenheim, called Paracelsus – the last three Archimedes, Galen, and Ptolemy. All were to register their impact on the learned world at approximately the same time. Indeed, the *De revolutionibus orbium* (Copernicus), *De humani corporis fabrica* (Vesalius), and the first major translation into Latin of the works of Archimedes all appeared in 1543.

The work of Paracelsus began to affect the learned world shortly after his

death in 1541 when his scattered manuscripts were collected and published extensively for the first time. It is to his work that we turn next since to a greater extent than the others, Paracelsus may be viewed as a herald of the Scientific Revolution. And yet, though his call for a new approach to nature was coupled with a venomous attack on the followers of the ancients, Paracelsus himself was typical of the Renaissance in his willingness to borrow freely from the very texts and authors he rejected in print.

CHAPTER II

The Chemical Key

A new interest in chemistry is very noticeable in the late Renaissance. Relatively few chemical books had been published in the period prior to 1550, but during the next century a veritable flood of chemical and medico–chemical texts was printed. Those who wrote these books or who printed older texts insisted on the importance of their work. They not only spoke of the large number of those who had abandoned the teachings of the ancients to follow their chemical philosophy, but they also frequently named the chemical authorities to whom their readers could turn for truth in philosophy and medicine. They all hoped that the doctrines of the ancients would soon be overturned and that their "new philosophy" of nature would triumph. On the other side, scientists as prominent as Johannes Kepler and the early mechanists Marin Mersenne and Pierre Gassendi were to write at length against the mystical philosophy of nature elaborated by the chemists. But why was chemistry such a center of debate? The immediate answer may be found in the controversial writings of Paracelsus, but to understand him we must look briefly at the chemical background to his work.

The Chemistry of the Latin West

Chemical texts were introduced to Western Europe in the twelfth century along with other treasures of Greek science, philosophy, and medicine by way of translation or abstraction (for the most part) from the Arabic. The early translations already characterize chemistry as a secret art, so secret that it is often difficult if not impossible to identify the original texts from which they were made. But when we pass beyond the indistinct scene of the twelfth century, we become aware of a rapidly increasing interest in this subject throughout the next two centuries prior to a decline in the

quantity – and quality – of new texts in the fifteenth century. There are numerous references to alchemical allegory in medieval literature, and Chaucer's late-fourteenth-century "Canon Yeoman's Tale" remains the best description of the gold-making charlatan.

Medieval alchemy incorporated much Aristotelian doctrine. The four elements of earth, water, air, and fire had served not only as the basis of Aristotelian physics but, in the form of the related four humors (blood, phlegm, yellow, and black bile), had also served as the bedrock of Galenic medical theory. The qualities associated with these elements (hot, cold, wet, and dry) were interchangeable and thus permitted the transmutation of one element into another. Islamic scholars had added to this a new theory of metals in the eighth century. They had taught that metals were composed of a hypothetical philosopher's (not actual) mercury and sulfur. When these two occurred in perfect proportion the resultant metal would be gold.

But along with Aristotelian and Islamic element theory, alchemy carried with it an aura of secrecy and mysticism. This may in part be a carry-over of the atmosphere in which the early metalworkers of Egypt operated. But a second source might well be the occult tradition of the mystical religions of late antiquity. Gnostic, neo-Platonic, and neo-Pythagorean elements did much to differentiate these alchemists from the students of optics, astronomy, and mathematics. And surely the religious currents run deep in the alchemical literature. The great work itself was seen as a religious experience, and processes and substances were frequently explained in terms of soul, body, and spirit.

Along with this allegorizing and mysticism the alchemist placed a new emphasis on observational evidence. We have already noted Paracelsus's call for the adept to learn from nature rather than books, but the same message is evident in the earlier literature. The fourteenth-century alchemist Bonus of Ferrara observed that

"If you wish to know that pepper is hot and that vinegar is cooling, that colocynth and absinthe are bitter, that honey is sweet, and that aconite is poison; that the magnet attracts steel, that arsenic whitens brass, and that tutia turns it of an orange color, you will, in every one of these cases, have to verify the assertion by experience. It is the same in Geometry, Astronomy, Music, Perspective, and other sciences with a practical aim and scope. A like rule applies with double force in alchemy, which undertakes to transmute the base metals into gold and silver . . . The truth and justice of this claim, like all other propositions of a practical nature, has to be

demonstrated by a practical experiment, and in no other way can it satisfactorily be shown."

Related to this emphasis on observation was the alchemist's interest in laboratory procedures. The medieval period saw great advances in distillation techniques. Far more efficient furnaces were built than had been available earlier. Now, with higher temperatures and better condensation, it was possible to add new reagents (most notably alcohol and the mineral acids) to the chemical laboratory. The Latin Geber (early fourteenth century, an assumed name referring to the eighth-century Jābir ibn Hayyān) produced the outstanding work of this sort describing equipment and chemical processes.

Geber made little reference to medicine, but this connection was to become an important aspect of medieval alchemy. The search for chemicals of pharmaceutical value appears among Islamic authors in the writings of the al-Rāzī (Rhazes) (c.854–925/926) and then frequently among his followers. In the West Roger Bacon noted in the *Opus tertium* (1267) that although many physicians used chemical processes to prepare their medicines, very few knew how to perform those works which led to the prolongation of life. His younger contemporary Arnald of Villanova (d. c. 1313) and the fourteenth-century author John of Rupescissa continued to emphasize the medical value of chemistry. By the early sixteenth century this form of scientific literature had blossomed into the many distillation books so very characteristic of the period. These all included descriptions of the chemical equipment needed for the production of oils and spirits from plant substances of all kinds. The benefits of these "quintessences" seemed so great that sixteenth-century editions of the ancient herbal of Dioscorides were furnished with a chemical appendix to bring it up to date.

This chemical knowledge was not considered to be in any way opposed to the science of the Aristotelians or the medicine of the Galenists. To be sure, there were some who complained about the conservatism of the schools, but alchemy had come to the West along with the rest of the body of ancient knowledge. It had been cultivated with classical philosophy and medicine in the Near East – and it was not to be immediately divorced from this earlier union. Nor is there any indication that chemistry was viewed as a dangerous rival discipline by physicians or natural philosophers.

The translation of the *Corpus hermeticum* by Ficino in 1463 added one more factor that was to affect the chemistry of the Renaissance. Fostering occult learning of all kinds, alchemy was shortly brought to the attention

of all learned men as an area of study that had not received proper attention in the past. Both Heinrich Cornelius Agrippa von Nettesheim and John Baptista Porta were to point to alchemy as a fundamental science for the understanding of nature. John Dee applied "geometrical method" through twenty-four theorems to the construction of his "hieroglyphic monad," a figure that closely approximated the alchemical symbol for mercury. In the course of this construction Dee felt that he had repeated the first steps of the Creation. The reader was promised the understanding of great mysteries and the entire work would appear to be no less than a veiled representation of the alchemical process itself. But Dee's emphasis was clearly of a piece with the spiritual mathematics favored by those Renaissance Pythagoreans who sought a key to the Creation in mysticism and numerical analysis. The truths of magic were avowed whereas more conventional mathematical proofs, chemical laboratory techniques, and practical medical applications were of relatively little interest. It was in this way that Dee felt that alchemy might be recognized as the most fundamental subject for the natural philosopher.

Nearly half a century earlier Paracelsus had found in alchemy a new basis for the theory of medicine. This, in turn, was to be developed into a universal philosophy of nature validated by the natural correspondences linking man and the world about him. And if Dee's mystical, "mathematicized" alchemy had little impact beyond a devoted circle of alchemists, the views of Paracelsus were to lead to a European debate relating to both medicine and natural philosophy.

Paracelsus: A Lifetime Search

Born near Zurich in the small town of Einsiedeln in 1493, Philippus Aureolus Theophrastus Bombastus von Hohenheim was only later referred to as "Paracelsus," or "greater than Celsus." As a child he was exposed to a heady mixture of Renaissance thought. His father was a country physician who dabbled in alchemy, and the son was never to lose his interest in either medicine or the chemical laboratory. Young Paracelsus was to study under the famed abbot and alchemist, Johannes Trithemius (1462–1516), and was to learn the lore of mines when he worked as an apprentice in the Fugger mines in Villach when his father moved there in 1500. This experience was to bear fruit later in his speculations on the growth of metals and his book on the diseases of miners, the first book ever written on an occupational health problem.

At the age of fourteen Paracelsus left home to study, and over a period of

more than two decades he traveled widely. He visited many universities and may have received a medical degree at Ferrara, but if so, he was willing to work in the far less prestigious position of surgeon with the armies that were ever on the move throughout Europe. By the third decade of the century his travels become easier to follow. Now in his thirties, he confined his travels to Central Europe, where he moved constantly from town to town both writing and offering his services as a physician. There were occasional moments of glory such as his appointment as municipal physician at Basel in 1527, but these were always short due to his rash temper. He made no effort to disguise his contempt for the universities and their academic circles. As for the physicians, they need hardly be considered:

"I need not don a coat of mail or a buckler against you, for you are not learned or experienced enough to refute even one word of mine . . . you defend your kingdom with belly-crawling and flattery. How long do you think this will last? . . . Let me tell you this: every little hair on my neck knows more than you and all your scribes, and my shoe-buckles are more learned than your Galen and Avicenna, and my beard has more experience than all your high colleges."

Such outbursts were to lose him position after position, for they offended even those who most wanted to help him. As a result he was constantly on the move; he died in Salzburg in 1541, where he had only recently been called by the bishop suffragan Ernest of Wittelsbach.

The Paracelsian Chemical Philosophy

At the death of Paracelsus there was little to indicate that his work would become the focal point for debate among scholars for more than a century. True, he had been a controversial figure during his lifetime, but relatively few of his voluminous writings had been published while he had been alive. The flood of Paracelsian texts began to issue from the presses only later. The legend of the man's near-miraculous cures began in the years after 1550 and soon there was a widespread search for his manuscripts, which were often published with notes and commentaries. Toward the end of the century vast collected editions were printed, and a whole school of Paracelsians battled with Aristotelians and Galenists over the course of natural philosophy and medicine alike.

Because of the late publication of the texts it is as proper to speak of the philosophy of the Paracelsians as it is that of Paracelsus. But even if we make this allowance the chemical philosophy is difficult to reconstruct,

partly because no simple textbooks were published and partly because the views of these men are alien to those of the twentieth-century scientist.

Actually there is much in the work of the Paracelsians that is reminiscent of other Renaissance natural philosophers. Above all, they sought to overturn the traditional, dominant Aristotelianism of the universities. For them Aristotle was a heathen author whose philosophy and system of nature was inconsistent with Christianity, a point of considerable concern during the Reformation. They stated that his influence on medicine had been catastrophic because Galen had uncritically accepted his work and the Aristotelian–Galenic system had subsequently become the basis of medical training throughout Europe. For them the universities were hopelessly moribund and unyielding in their adherence to antiquity.

The Paracelsians hoped to replace all this with a Christian neo-Platonic and Hermetic philosophy, one that would account for all natural phenomena. They argued that the true physician might find truth in the two divine books: the book of divine revelation – Scripture – and the book of divine Creation – nature (Figure 2.1). Thus, the Paracelsians applied themselves on the one hand to a form of biblical exegesis, and on the other to the call for a new philosophy of nature based on fresh observation and experiment. An excellent example of this may be found in the work of the important early systematizer of the Paracelsian corpus, Peter Severinus (1540–1602), physician to the king of Denmark, who told his readers that they must sell their possessions, burn their books, and begin to travel so that they might make and collect observations on plants, animals, and minerals. After their *Wanderjahren* they must "purchase coal, build furnaces, watch and operate with the fire without wearying. In this way and no other you will arrive at a knowledge of things and their properties."

One senses a strong reliance on observation and experiment in the work of these men even though their concept of what an experiment is and its purpose was often quite different from our own. At the same time one notes an underlying distrust of the use of mathematics in the study of nature. They might well, as Platonists, speak of the divine mathematical harmonies of the universe. Paracelsus, in addition, spoke firmly of true mathematics as the true natural magic. But it was more customary for the Paracelsians to react with distaste to the logical, "geometrical," method of argument employed by the Aristotelians and Galenists. They condemned this "mathematical method" along with the traditional scholastic emphasis on geometry and they very specifically attacked mathematical abstraction in the study of natural phenomena – particularly the study of local motion. Their reason for this was primarily religious, and they were particularly in-

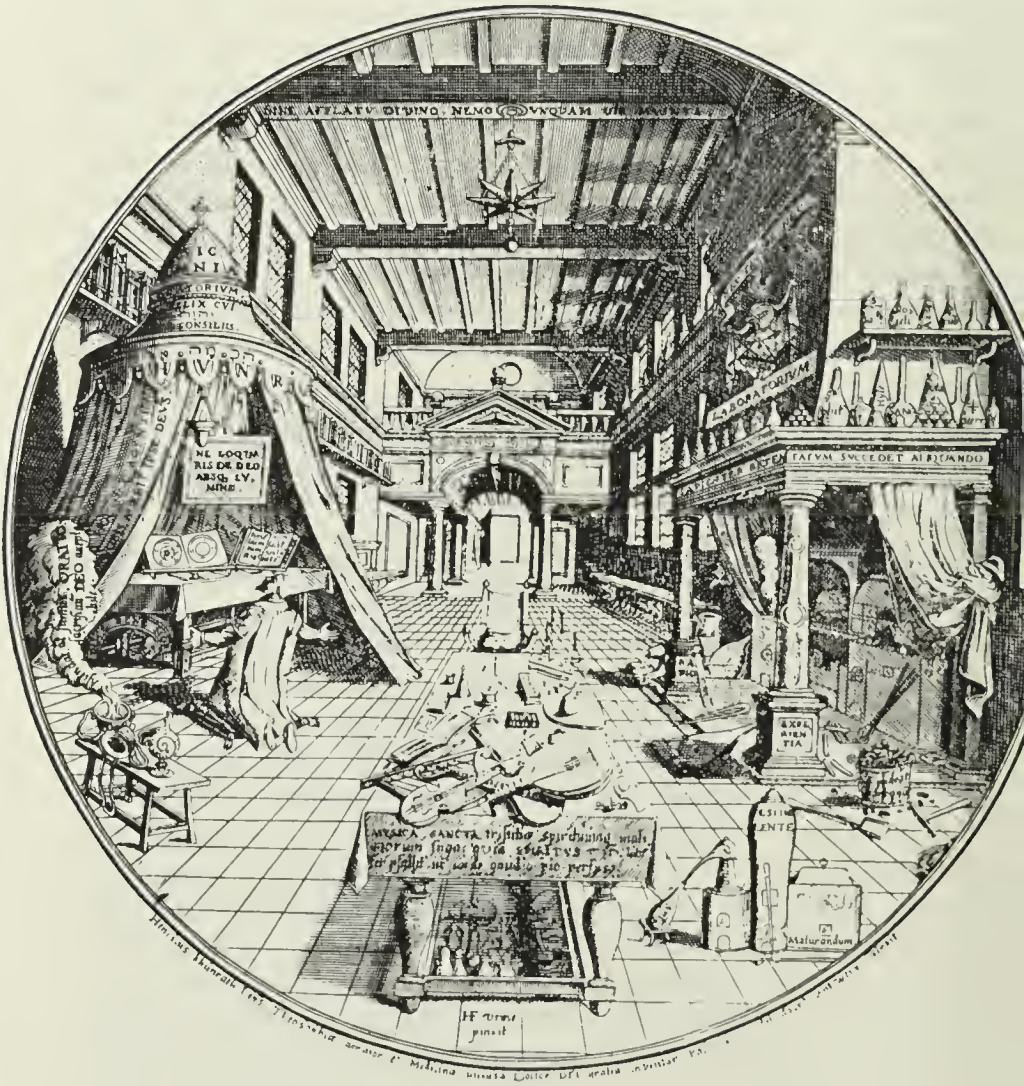

Figure 2.1. The true chemical philosopher learns through divine revelation as well as chemical studies. From Heinrich Khunrath, *Amphitheatrum sapientiae* (1609). From the collection of the author.

censed by the *Physics* of Aristotle. There – through the study of motion – it was argued that the Creator God must be immobile. The Paracelsian chemists of the period of the Reformation stated firmly that any argument imposing such a restriction on the omnipotent Deity could not be ac-

cepted – and that for this reason alone the texts of the ancients were sacrilegious and must be discarded. The chemical philosophy was to be a new science based firmly on observation and religion. Those who turned to quantification might recall that God had created "all things in number, weight and measure." This was interpreted as a mandate for the physician, the chemist, and the pharmacist – men who weighed and measured regularly in the course of their work (Figure 2.2).

If the Paracelsians rejected what they called the "logico–mathematical" method of the schools, they turned to chemistry with the conviction that this science was the basis for a new understanding of nature. It was an observational science, and its scope was universal. These claims were to be found in the traditional chemical texts. For Paracelsus alchemy had offered an "adequate explanation of all the four elements," and this meant literally that alchemy and chemistry might be used as keys to the cosmos either through direct experiment or through analogy. Paracelsus explained the Creation itself as a chemical unfolding of nature. The later Paracelsians agreed and amplified this theme. Gerhard Dorn (fl. 1565–1585) gave a detailed description of the first two chapters of Genesis in terms of the new chemical physics, and Thomas Tymme argued that the Creation had been nothing but an "Halchymicall Extraction, Separation, Sublimation, and Conjunction."

The chemical interpretation of Genesis helped to focus attention on the problem of the elements as the required first fruit of the Creation. Although the Paracelsian *tria prima* (salt, sulfur, and mercury) was a modification of both the earlier sulfur-mercury theory of the metals and other elemental triads, it has a special significance in the rise of modern science. The Aristotelian elements (earth, water, air, and fire) served as the basis of the accepted cosmological system. They were used by the alchemists as a means of explaining the composition of matter, by the physicians (through the humors) as a system for the interpretation of disease, and by the physicists as the basis for the proper understanding of natural motion. The introduction of a new elemental system thus ran the risk of calling into question the whole framework of ancient medicine and natural philosophy.

Although the new principles can properly be interpreted as part of an attack on scholastic philosophy, it is clear also that they led to considerable confusion. Paracelsus had not clearly defined these principles, and, indeed, they were of little value in the development of modern analytical chemistry inasmuch as they were described as differing qualitatively in different materials. Nor had Paracelsus offered the principles specifically as a replacement for the Aristotelian elements. Rather, he had used both systems –

Figure 2.2. The earliest illustration of an enclosed analytical balance is to be found in this picture of an alchemical laboratory. From the *Theatrum Chemicum Britannicum*, ed. Elias Ashmole (1652). Courtesy of the Department of Special Collections, The University of Chicago.

and often in a seemingly contradictory fashion. By the fourth quarter of the sixteenth century we find element theory in a state of flux, with chemists choosing from observational evidence and Paracelsian texts as they saw fit. Nevertheless, from the texts of this period we can see that the chemical physicians were turning in increasing numbers to the three principles as a means of explanation. Some were attracted by the trinitarian analogy of body, soul, and spirit, whereas others turned to them in search of an alternative to the humors. For chemical theorists they represented philosophical substances that might never be isolated in reality, whereas for the practical pharmacist they were nothing else but his distillation products. It was not uncommon for a medicinal herb to yield a watery phlegm, an inflammable oil, and a solid, and it was felt that these at least indicated the presence of the primal principles of mercury, sulfur, and salt.

The concept of a chemical universe went beyond the chemical interpretation of the Creation and the problems of element theory. Those authors interested in meteorology explained thunder and lightning as a combination of an aerial sulfur and niter analogous to the explosion of sulfur and saltpeter in gunpowder. Similarly, Paracelsian authors were the first to offer a hypothesis meaningful for the development of agricultural chemistry. Seeking a cause for the beneficial effects of manuring in farming, they correctly postulated that the manure offered essential soluble salts to the soil.

Indeed, for the Paracelsians, the earth was seen as a vast chemical laboratory and this explained the origin of volcanoes, hot springs, mountain springs, and the growth of metals. The old concept of an internal fire was given as the explanation of volcanoes, which were understood as the eruptions of molten matter through surface cracks (Figure 2.3). Mountain streams were explained in an analogous fashion. Here they argued that subterranean water reservoirs were distilled by the heat of the central fire. As this vapor reached the surface, mountains acted as chemical alembics, and the result was the "distilled" mountain stream. Yet some rejected the possibility of such a fire, arguing that the air requisite for such a conflagration did not exist within the earth. Henri de Rochas (fl. 1620–1640) suggested that the heat of mineral-water springs derives from the reaction of sulfur and a nitrous salt in the earth. The English physician Edward Jorden (1569–1632) offered a more comprehensive chemical alternative. A thorough vitalist like most chemists of the period, Jorden accepted the commonly held notion of the growth of metals, but accounted for it in a new way. He turned to the alchemical process of "fermentation," which he defined as a heat-producing reaction requiring no air. This, he argued, must be the cause of inorganic growth. This new source of heat enabled one

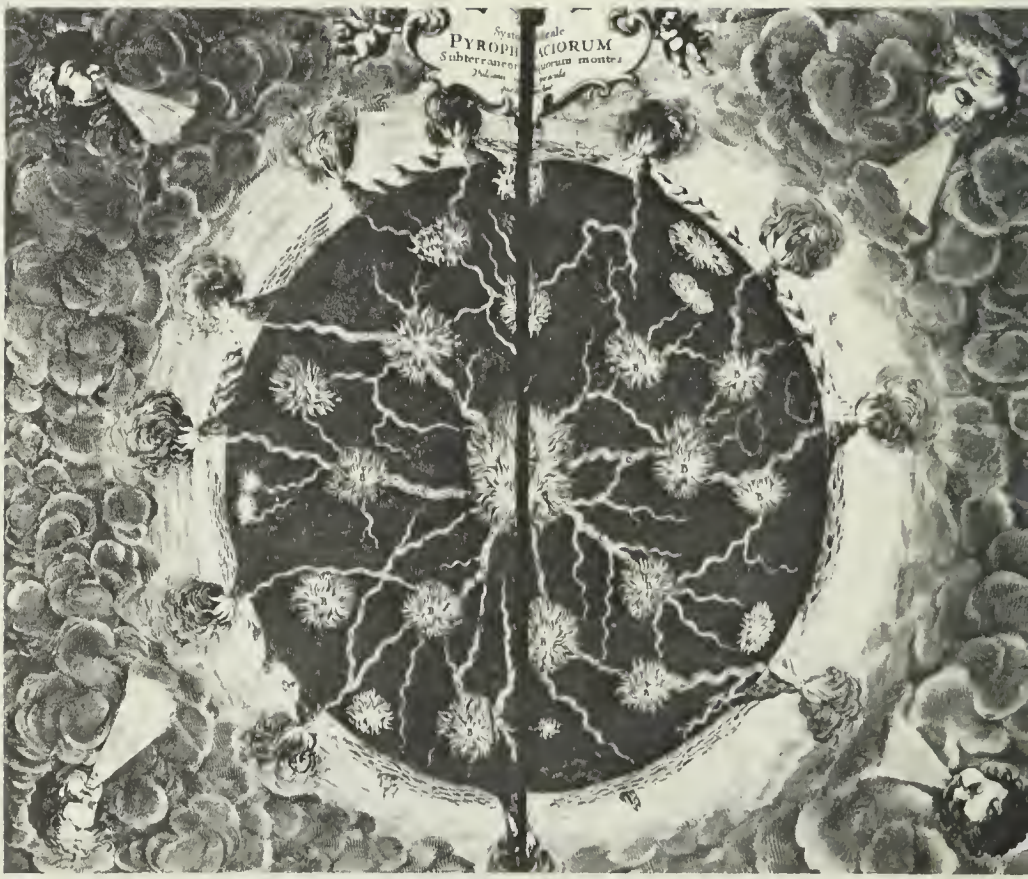

Figure 2.3. Diagram depicting the interrelation of volcanoes and the central fire. From Athanasius Kircher, *Mundus subterraneus* (1678). Courtesy of the Department of Special Collections, The University of Chicago.

to understand volcanoes and mountain streams without the troublesome notion of the central fire.

The Microcosm and Medical Theory

The Paracelsian chemical philosophy was considered to be a new observational approach to all nature, but from the beginning it had a special appeal for physicians. Paracelsus had insisted that God rather than the constellations had created him a physician; his followers repeated this and added that because of its divine origin medicine stood above the other sciences. Here they both reflected the priest–physician concept of Renaissance neo-

Platonism, and it is likely that their ultimate source may be found in Ecclesiasticus 38:1, "Honor the physician for the need thou hast of him: for the Most High hath created him." Indeed, for Paracelsus the role of the physician might properly be compared with that of the true natural magician.

Paracelsus and his early followers firmly believed in the macrocosm–microcosm analogy. Man is a small replica of the great world about him, and within him are represented all parts of the universe (Figure 2.4). At all times it was considered fruitful to seek out correspondences between the greater and lesser worlds, and the theory of sympathy and antipathy was employed to explain universal interaction. In contrast to Aristotelians, who insisted on action through contact, the Paracelsians found no difficulty in accepting action at a distance. It is thus easy to understand why Paracelsian Hermeticists should have been among the first to defend the experimental research of William Gilbert on the magnet. In the field of medicine, the controversial weapon salve cure (cure by sympathy involving treatment of the weapon rather than the wounded person) surely assumed the possibility of action at a distance.

For the Paracelsian the humoral theory of Galenic medicine was no longer adequate. The traditional explanation of disease as an internal imbalance of the humors was rejected by Paracelsus. He preferred to emphasize local malfunctions within the body that were ascribed to one of the three principles. A major cause of disease for him was to be found in external seedlike factors that were introduced to the body through the air, food, or drink. These localized themselves and then grew in specific organs. Here an analogy coud be drawn between the macrocosm and the microcosm. In the same fashion that metallic "seeds" in the earth resulted in the growth of metallic veins, "seeds" of disease grew within the body while they combated the local life force of a specific organ. This life force separated pure substance from waste in a manner analogous to the alchemist who sought to isolate pure quintessences from gross matter in his laboratory.

The relationship of the macrocosm to man had further chemical implications. The French Paracelsian Joseph Duchesne (c. 1544–1609) exemplified the persistent search for chemical analogies among the Paracelsians when he spoke of respiratory diseases in terms of the same distillation analogy utilized by other iatrochemists (or medical chemists) when explaining the origin of mountain streams. Special significance was attached to the air, recognized as essential for the maintenance of both fire and life. If, on the one hand, an aerial sulfur and niter might combine to cause thunder and lightning in the sky or hot springs in the earth, on the other hand, they might react within the body when inhaled to generate diseases charac-

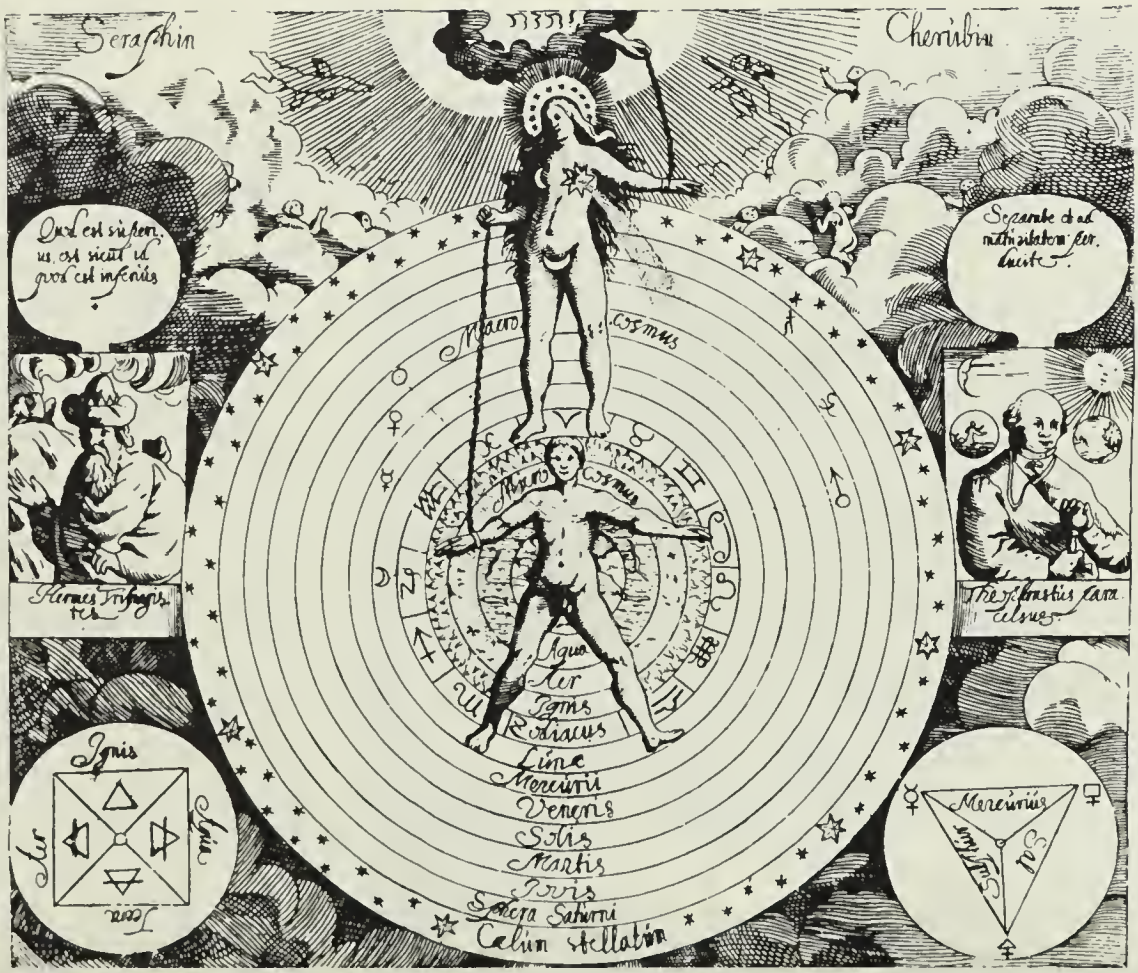

Figure 2.4. Man as the microcosm joined to his creator by the chains of nature, depicted as a young woman. Note the portraits of Hermes and Paracelsus plus the diagrams of the four elements and the three principles. From Tobias Schütz, *Harmonia macrocosmi cum microcosmi* (1654).

terized by hot and burning qualities (Figure 2.5). By the early seventeenth century aerial niter had become associated with a life force requisite for man. Indeed, this life force was on occasion identified with the *spiritus mundi.* It was postulated that after having been separated from gross air in the lungs, this substance was formed into arterial blood. Inasmuch as they maintained this concept – or modifications of it – it is little wonder that we find seventeenth-century Paracelsians rejecting the common practice of bloodletting. This operation, they argued, would only diminish the essential life force of the patient. At the same time, the rejection of bloodletting served to reflect their opposition to traditional humoral pathology.

If the Paracelsian chemical philosophy of nature provided a conceptual framework for the iatrochemist, it also provided a basis for his practical work. Because of the importance of heat and of fire, both the new chemical analysis of urine and the new chemical doctrine of signatures were to be characterized by distillation procedures. Similarly, in a search for the ingredients of medicinal waters at spas the Paracelsians furthered the development of analytical chemistry. A long medieval tradition in this field had resulted in the development not only of isolated tests, but of real analytical procedures, and it is understandable that the Paracelsians quickly adopted this tradition and added to it. By 1571 Leonard Thurneisser (c. 1530–1596) was using quantitative methods, solubility tests, crystallographic evidence, and flame tests, and early in the next century Edward Jorden was advocating the red-blue color change of "scarlet cloth" as a regular test for those liquids that we would classify as acids and bases. The work of these men provided the basic information necessary for Robert Boyle's analytic research later in the century.

The results of the new chemical analyses were put to practical use. Chemists could now give directions for the preparation of artificial mineral waters to those who could not travel to the spas, and at the same time this analytical information added an argument for the use of chemically prepared medicines. The Paracelsians argued passionately that theirs was a new and violent age – one that had spawned ravaging diseases unknown to the ancients. (They were particularly appalled by the venereal diseases.) As a result they needed new medicines, more potent than the traditional Galenicals prepared from herbs. Their meaning was clear: These new medicines were their chemically prepared metals and minerals. The Paracelsians were not innovators in this. Nevertheless, as R. Bostocke stated in 1585, the true Paracelsian could be distinguished from others through his careful attention to dosage and his use of the chemical art to extract only the valuable essence of dangerous minerals. Furthermore, in his defense of these

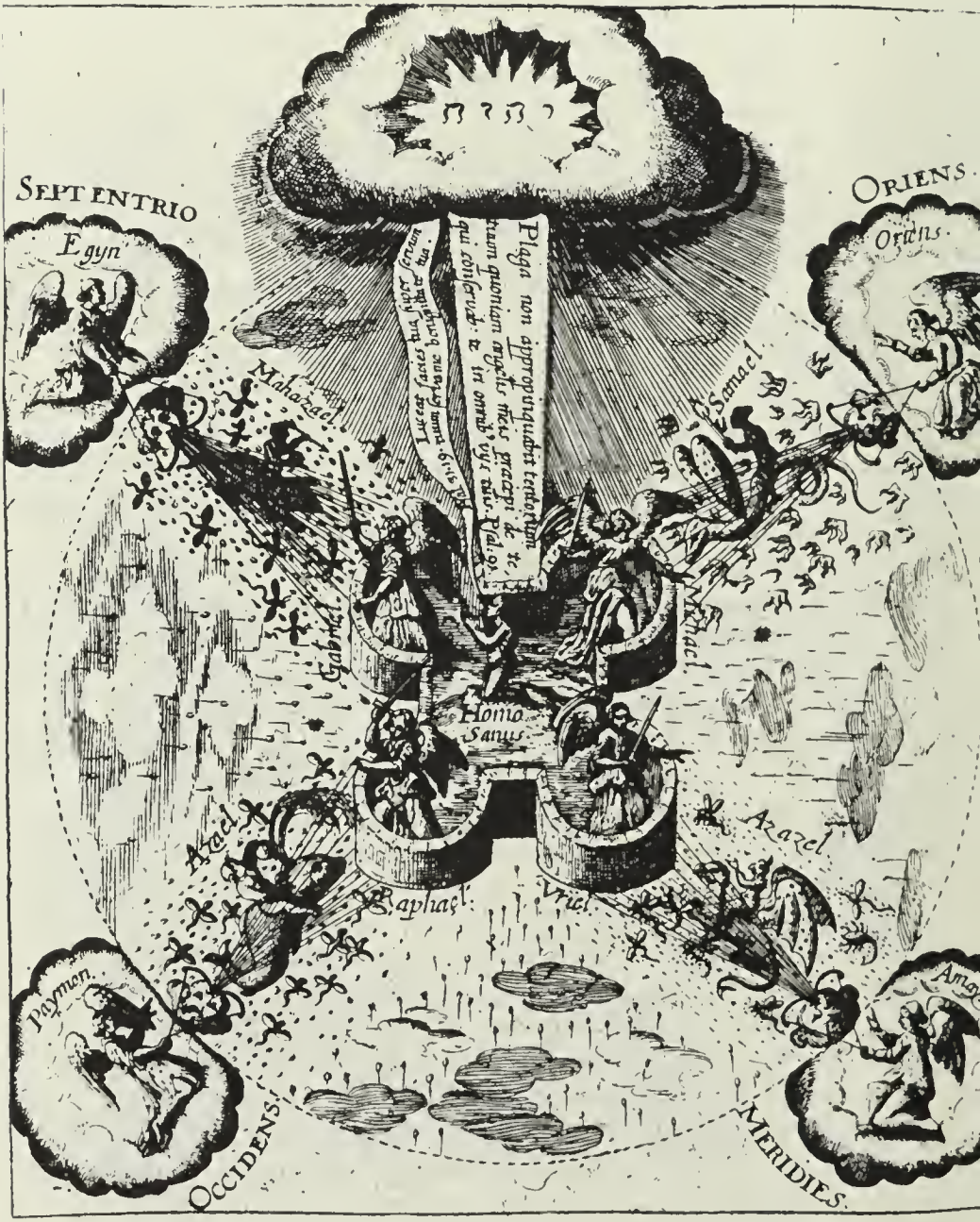

Figure 2.5. Man besieged in his castle of health. From Robert Fludd, *Integrum Morborum Mysterium* (1631). From the collection of the author.

medicines (1603), Duchesne relied upon the spa-water analyses to demonstrate that minerals had beneficial medicinal effects.

The defenders of the traditional *materia medica* were far from satisfied by apologies for the chemical medicines, and, in truth, their fear of the new drugs was not groundless. Paracelsus had broken with the Galenic dictum that "contraries cure" and turned instead to Germanic folk medicine, which insisted that "like cures like." The physician was told to investigate poisons rather than bland vegetable concoctions. That poison that causes a disease should now – in proper form – become its cure. And although the chemists sought to remove the toxic qualities, the medical establishment were not reassured by this claim. For them many of the proponents of the new drugs were uneducated charlatans. In a Galenic text the very name "Paracelsian" had an unsavory connotation. Thomas Erastus (1524–1583) accused Paracelsus of advocating the internal use of lethal poisons (1572). John Donne (1573–1631), in his comparison of the innovations of Copernicus and Paracelsus, admitted only the latter to the inner sanctum of Satan's lair as the governor of the "Legion of homicide Physicians." In answer chemists spoke ever more forcefully in defense of their medicines and methods. In the mid-seventeenth century it was suggested that several hundred sick poor people be taken from the hospitals and the military camps. They were to be divided into two groups, one to be treated by the Galenists, the other by the chemists. The number of funerals would determine whether the chemical or the traditional medicine had triumphed. The trial was never made, but the fact that it was proposed indicates the heat of the controversy.

The new drugs became a subject of intense debate at the university level in the early seventeenth century. The most inflammatory pamphlets appeared at Paris in the first decade of the century, but these were soon translated and published in other parts of Europe, with histories of the conflict being written as early as 1606. In London the fellows of the Royal College of Physicians had for several decades been engaged in plans for the publication of an official pharmacopoeia. When the French chemical physician Theodore Turquet de Mayerne (1573–1655) moved to London as the physician to King James I, he increased their interest in the new chemicals. And when the pharmacopoeia did appear in print in 1618, it was seen that a careful compromise had been reached. While the bulk of the volume was devoted to the traditional Galenicals, several sections were reserved for the new chemically prepared medicines. Official sanction was given to them both there and in the preface, which called attention to their efficacy in difficult diseases.

We may then speak properly of an increasing polarization between the Hermetic physicians and the Galenists. Yet at the same time the position of the London College of Physicians shows the eventual tendency toward compromise on the difficult question of the internal use of the new medicines. Among the chemical physicians themselves an ever-increasing number sought to maintain chemistry as the basis of a new philosophy of nature, but rid it of its most mystical and least experimental aspects. Influential iatrochemists such as Daniel Sennert (1572–1637) and Andreas Libavius (1540–1616) agreed with Paracelsus that chemistry was a proper basis of medicine and was thus the chief of all sciences. But they did not wish to see the works of Aristotle, Galen, and Hippocrates discarded and burned in the marketplace. Rather than resorting to polemics, the true physician should examine both the old and the new medicines and accept the best of both. For many seventeenth-century iatrochemists the chemical philosophy could be safely followed because this seemed to provide a new observational basis for the sciences. But many of the same men were disturbed no less than the Galenists – or later, the mechanical philosophers – by the mystical, alchemical cosmology of some of their fellows. Thus, the reader of this literature will find a bewildering spectrum of medical and chemical views. These books and pamphlets encompass everything from traditional allegorical alchemy to practical chemical pharmacopoeias. And, as we shall see, the debate itself was of great concern to both physicians and scientists until well into the seventeenth century.

We might pause to reflect on the significance of the chemistry and the medical debates it engendered in this period of the late Renaissance. What had the Paracelsians accomplished? How had they influenced medicine and science in this period?

Above all, Paracelsian medicine represented a reaction against the traditional veneration for antiquity. The early Paracelsians spoke harshly of Aristotle and Galen (if not always Hippocrates) and they turned instead to the recently translated Hermetic, alchemical, and neo-Platonic texts. A vitalistic universe founded on the macrocosm–microcosm analogy and the divine office of the physician was the basis for a new Christian understanding of nature as a whole. In their drive for reform the Paracelsians proceeded to strike at the very foundations of the older system. Both the Aristotelian elements – upon which the old cosmology was founded – and their attendant humors – upon which Galenic medicine depended – were questioned. Chemists now turned to the three principles as an explanatory device, and Paracelsian physicians spoke in terms of local seats of disease governed by internal *archei* rather than the imbalance of fluids.

The Paracelsian answer to antiquity was best expressed in the emphasis on observation and experience as a new basis for the study of nature. Surely the Paracelsians were not alone in this plea, but their special interest in chemistry as a guide for the study of man and the universe distinguishes them from other Renaissance philosophers of nature. Their extensive use of chemical equipment in distillation experiments and their constant reference to chemical analogies as a means of understanding all natural phenomena place them squarely in the Hermetic–alchemical tradition.

The medicine of the Paracelsians was strongly tinged with chemistry, but not with mathematics. While they might still pay lip service to the certainty of mathematical proof, in fact their concept of quantification was closest either to neo-Pythagorean mysticism or to practical measurements by weight. Mathematical abstractions of natural phenomena and geometrical proofs savored of scholasticism, which was plainly to be avoided. Logic itself was suspect as a form of the "mathematical" science and medicine of antiquity. The medico-science of the Paracelsians thus tended to be a less rather than a more mathematicized approach to nature than that of the past.

The opinions of these chemical physicians were set forth with conviction, but often with little tact. They decried the current overreliance on antiquity. They called for a new medicine and a new natural philosophy based on chemically oriented observations and experiments. And they demanded educational reforms so that their "Christian" concept of nature might be taught at the universities. On these points they came into direct conflict with tradition. Yet they argued no less vehemently amongst themselves. Here they debated questions such as the place of mathematics in the formation of the new philosophy, the truth of the elements, the reality of the macrocosm–microcosm analogy, and the meaning of astral emanations. We can, of course, credit the Paracelsians with specific advances – their concept of disease or their recognition of the importance of chemistry for medicine (both as a basis for the understanding of physiological processes and as a new source for medicinal preparations) serve as excellent examples. And there is little question that some of the "modern" concepts of the late seventeenth century have their roots in the "nonmodern" concepts of the iatrochemists of the preceding century. Nevertheless, it was primarily by defining their vision of a new science based on medicine and interpreted through chemistry that they found themselves engaged in a debate that was to be influential in the definition of significant aspects of modern science.