nius and Ehrlich over immunochemistry is particularly relevant for understanding how methodology and theory are shaped by disciplinary constraints. The case studies in these two useful biographies then can help philosophers of chemistry identify what makes an explanation 'chemical', 'physical', or 'biological', or even if such a demarcation is possible.

Peter J. Ramberg:
Max-Planck-Institute for the History of Science, Wilhelmstr. 44, 10117 Berlin, Germany;
ramberg@mpiwg-berlin.mpg.de

LAWRENCE M. PRINCIPE, *The Aspiring Adept. Robert Boyle and His Alchemical Quest* (Including Boyle's 'Lost' *Dialogue on the Transmutation of Metals)*, Princeton University Press, Princeton/NJ, 1998, -xiv, 339 pp. (ISBN 0-691-01678-X)

Especially concerning extraordinary personalities, history is often presented as a one-sided view. The history of science is not an exception to this condition. Throughout the course of time, in scholarly works and ever more in textbooks, such a personality turns into a stony monument standing high on the pedestal of his or her crucial discovery. The authentic person disappears in the shadow thrown by the fossilized hero. As the author of the reviewed book puts it in the Introduction, the figure is well-known, but the true subject remains hidden. In this respect, it is particularly interesting to analyze the approach to the history of alchemy and chemistry, because it was the latter that finally won the battle. The notorious fact is that history was always written by the winners. From this point of view, it was often felt as something inconvenient to recognize that some great scientists, ever exact scientists, devoted a lot of time to such an activity as alchemy, which was looked upon with suspicion especially since the European Enlightenment. This attitude prevailed even in the relatively recent past when hardly anybody dared to touch monuments erected one or two centuries ago. This was the fate of Isaac Newton whose physical laws became the cornerstones of science, but whose alchemical activity remained hidden to broader public (and still does not appear in most textbooks). Newton is portrayed as an immortal hero, but not as a living man. Thanks to the immense work of a few scholars (B. Jo Dobbs, K. Figala) this famous physicist gradually emerges as a man whose interests were far broader, and as an alchemist who spent a significant part of his life in a vain search for ways of transmutation. A similar attempt, but from the other

end, which appeared recently in the historiography of alchemy was W.R. Newman's analysis of George Starkey's life and work. In this work, the mysterious Philaletha revered by the alchemical community of past centuries turns back into a living (and very interesting) personality.

Now, a further analysis of this kind has appeared. This work fills the deep gap between the scientist-Boyle known from textbooks, and the forgotten or intentionally omitted alchemist-Boyle. Principe's book is an important contribution, because Robert Boyle can serve as a representative of confusion and of intentional changes that have been linked with this scientist's history over the past three centuries. An often remembered story is how King Charles II laughed during a session of the Royal Society when he heard that somebody could be as foolish to make experiments with the air. The King was in fatal error: Boyle-Mariotte's law paved its way into science and made its authors immortal. Behind this law, however, Boyle as an alchemist fully disappeared. Later historiography often simplified his picture creating a portrait of a founder of modern science and claiming his *Sceptical Chymist* to be the first decisive turn that has eventually led to the development of modern chemistry. In the light of this approach, it was considered almost impolite to range this man among fervent alchemists. Yet, the 17th century was a period of deep transition, a century in which scientists vacillated between correctly explained chemical reactions and Sirens of the past whose voice of the transmutation of base metals into precious ones could still be heard. Newton was already mentioned as this kind of scientist and further examples can be easily found, like J. R. Glauber – and R. Boyle.

Prinicipe's book is neither a full biography of Boyle, nor a complete study of his scientific work. It is a book focused on his alchemical pursuits, which were only one side of his interests. However, even this is not quite a thorough description, because the reader finds only individual soundings into Boyle's alchemical world. It was too complex and broad a world to be encompassed within one book, and this study will surely continue; for this continuation, Principe's book forms a firm foundation. The titles of the chapters are telling: "Alchemy and Chemistry"; "Skeptical of the Sceptical Chymist"; "Adepti, Aspirants, and Cheats"; "Boyle and Alchemical Practice"; "Motivations"; "Truth, Medicine, and Religion", … Three appendices are especially creditable: 1. "Robert Boyle's Dialogue on the Transmutation and Melioration of Metals"; 2. "Interview Accounts of Transmutation and Prefaces to Boyle's Other Chrysopoetic Writings"; 3. "Dialogue on the Converse with Angels Aided by the Philosopher's Stone". These appendices are the results of a deep and thorough study of Boyle's scattered notes. Originally only fragments, they were put together by the author into texts that make it possible to get better insight into Boyle's attitude toward alchemy.

In the enumeration of chapters, the first one was omitted: "Alchemy and Chemistry; The Crucial Note on Terminology and Categories". Here, unfortunately only briefly, the problem of terminology is discussed, chiefly involving what should be denoted as alchemy and what as chemistry. But it is not enough to consider only these two words; as activities based on chemical and/or metallurgical operations developed, further terms appeared: '*spagyria*', '*chemiatria*', '*iatrochemistry*', or more specific ones like '*chrysopoeia*' and '*argyropoeia*'. The 17th century especially yields a picture of confusion with respect to the use of such a branched terminology. This important question was discussed in more detail in a joint paper by W.R. Newman and L.M. Principe [*Early Science and Medicine*, **31** (1998) 32-65]. This confused terminology can be further documented on the example of Michael Maier, another prominent personality of the 17th century alchemical sphere. Maier wrote about '*chymia secreta*' in his *Atalanta fugiens*; and in *Examen Fucorum Pseudo-*

Chymicorum we can find '*chymia vera*' performed by '*Artifex chymicus*', while in the Dedication he criticized '*fucos Alchymicos*' or '*Pseudo-chymicos*'. Michael Sendivogius, his contemporary, published *Dialogus Mercurii, Alchymistae, ...* This lack of unity in terminology continued well into the subsequent century: C. Horlacher wrote about '*Chymia oder wahre Alchymia*', as chemistry was the 'true alchemy' for him. These expressions became synonymous in his vocabulary. As is apparent, the problem of terminology is complex and more efforts are necessary to clear it of the old traditional concept of the all-embracing, but very general term 'alchemy'.

Discussion of Boyle's work has always revolved around his *Sceptical Chymist* as the central axis because this book was generally considered to be the crucial milestone, or foundation stone, on which modern chemistry was built. Therefore, Principe also begins his analysis with this work; but the more we read his conclusions, the more skeptical are we as to what should be thought of Boyle's book. From a concrete milestone, it gradually turns into a filter that should separate wheat from the chaff: true *adepti*, among whom Boyle counted himself, from 'vulgar chymists', including here iatrochemical pharmacists, Paracelsian systematizers and others who did not penetrate into the secrets of 'chymical philosophers' as Boyle in his opinion obviously did. Particularly telling is the analysis of the appendix to the 1680 edition of the *Sceptical Chymist*. Here Boyle maintained the real existence of metallic '*Mercurii*', claiming even that he is in possession of "portions of Mercury's of more than one or two metals". Rejection of the elements, accepted traditionally as Boyle's negative attitude toward alchemy as such, concerned actually only the Paracelsian *tria prima*, while both Mercuries and Sulphurs of metals did exist according to Boyle. Principe shows, on the example of this work, that the question still remains open as to what routes have led to modern chemistry. The answer is a complex one, not only because of the complex nature of chemico/alchemical activity in the 16th and 17th centuries, but because some of the roots should be sought for in the more distant past (with Pseudo-Geber, for example).

The complexity of the origins of chemistry would call for special discussions. The 17th century saw an increase in the number of postulated 'elements' or 'principles' as the constituent parts of metals. Their number increased in various ways. For example, F. Clinge distinguished in his *Richtigen Weg=Weiser* (Berlin 1701) as many as eight constituents, three of which were identical with the Paracelsian *tria prima*, with the rest denoted as '*excrementa*'. The date of his book proves that this debate still continued in the beginning of the 18th century. The origin of modern chemistry should be rather described as a continuous process in a way that can be best characterized as 'two steps forward, and one step backward'. Many people, famous as well as lesser known, contributed to this evolution. And many, like Boyle, stood at the threshold – they refuted some older teachings, suggested their own views, and were sometimes also mistaken. Typical was the case of phlogiston, when one error, the elements of alchemists, was replaced by another error. Anyway, in the course of their work these scientists sometimes made real chemical discoveries. For a long time such discoveries were incorporated into alchemical teaching, sometimes forcibly, as when Sendivogis' observations with his *sal centrale* were put into accord with the words of the *Emerald Table*. The problem of oxygen is one of the best examples of the gradual transition from alchemy to chemistry [Z. Szydlo, *Ambix*, **43** (1996) 80-96]. In the 17th century, however, there were already more doubts accumulating as to whether given reaction was actually some kind of transmutation. It took another century for these doubts to prevail.

As the title of the reviewed book suggests, the central problem is Boyle's belief in transmutation. This scientist counted himself among those adepts who claimed to possess the highest se-

cret of *chrysopoeia*, or to be at least close to it, and in this respect he acted in a way typical of alchemists. The first characteristic feature that advances through the whole history of alchemy like Ariadne's thread is secrecy. In all cultures where this science appeared, the crucial texts were often encrypted. This practice was not solely a specialty of alchemy; craftsmen likewise hid their technical information. As a typical example, the recipe for alcohol distillation from wine can be given as it appeared in the *Mappae clavicula*. Here, a classical cipher was used. Ko Hung's use of calendar symbols for chemical substances was a form of coding the text. Boyle made use of both approaches to make his text illegible to outsiders. His cipher was more perfect than that used in the *Mappae clavicula*: after a keyword that had to be composed of letters without repetition (for example ANGELUS) the rest of the alphabet was written in random order. In the second row, the alphabet was written again in such a manner that each letter in the enciphered text should be found in the top row and exchanged for the letter in the bottom row. This kind of substitution cipher could not be broken by any outsider unless he knew the key. Boyle also used code by either replacing words with their Greek or Hebrew equivalents, like '*cassiteros*' for tin, or by using meaningless words like '*durca*' or '*ormunt*'. The only rule in the latter case was that the code word begins with the letter of the alphabet following the first letter of the original, coded word. Principe wrote earlier on Boyle's secrecy [*Ambix*, **39** (1992) 63-74]. This very thorough approach in keeping his messages and notes secret only documents the stress Boyle laid on alchemical information. Simultaneously, the readers of Principe's book are warned about what they can expect when they try to study Boyle's works.

The second general feature traceable in later European alchemy was the argumentation in favor of transmutation using eyewitnesses, or *testimonia*. Recognized scholars were cited who described the alleged transmutation of base metals performed in their presence. The most common testimonies were those of Helvetius (J.F. Schweitzer, 1625/30 - 1709) and J.B. van Helmont (1579 - 1644); there are doubts concerning the authenticity of the latter because it appeared posthumously, supposedly written, at least according to some authors, by his son. Boyle surprisingly drew upon another source: Wenzel Seyler, an Augustinian (?) monk from Bohemia [recently, some details about Seyler's life appeared: B. Koch, *Numismatische Zeitschrift* **101** (1990) 91], who stood in high esteem at the court of the Austrian emperor. For his seemingly successful transmutation he was even ennobled to Wenzel von Reinsburg, but in spite of this, he was for some time still of dubious reputation. Later, his '*Meisterstück*', a famous medallion on the Emperor Leopold I and dated 1677, returned him to his former glory. One third of this oval, 40 x 37 cm piece, weighing 7200 grams, and allegedly made of silver, was dipped into the 'tincture', and the submerged part turned into pure gold. A chemical analysis performed in 1932 shed light on the secret of this process: the metal was actually an alloy of Au-Ag-Cu, also containing minor impurities. When dipped into diluted nitric acid, all metals except for gold dissolved leaving a pure surface of this metal. Contrary to the rather mysterious '*testimonia*' by Helvetius and van Helmont, in this exceptional case we know today the principle of the method used by the alchemist. Boyle could not suspect the truth behind this reaction, and it is no wonder that he took Seyler's experiment for granted as transmutation and used it as his convincing argument in favor of this process. Seyler's transmutation was repeatedly remembered in alchemical works, but usually as only one of many examples. Boyle's acceptance of this story can be compared with '*testimonia*' and it is in this respect rather unique.

In spite of his belief in transmutation, Boyle belonged among 'skeptical alchemists' who did not promise untold riches from this miraculous process as their predecessors used to do in the previous

centuries. On the contrary, he claimed that no financial gain should be expected. This is an interesting turn in thinking that appeared by that time. From a modern point of view, we can say that, without economic advantage, the search for transmutation became a purely scientific undertaking. It was a question of principle to prove the possibility of transmutation *per se* and to defend *chrysopoeia*. This skepticism concerning the economic effect of alchemical work appearing in the 17th century was even more pronounced in the subsequent century when the last ardent adherents of alchemy fought their lost battle. We can find an analogous attitude toward the financial prospects of alchemists in J.K. Creiling's *Die Edelgeborne Jungfer Alchymia* (published anonymously in 1730), or in Ch. Bergner's *Chymische Versuche und Erfahrungen* from 1792. Boyle was one of pioneers of this skepticism.

In the 17th century, alchemists, pharmacists, and craftsmen had already accumulated rich information about various chemical reactions. Many experiments could be explained (of course, not yet in the terminology of modern chemistry) as processes different from transmutation on the basis of the then attained level of knowledge. This state of things was unavoidably reflected in Boyle's writings, merely because he was a skilled chemist. Unfortunately Principe's book does not cite any of Boyle's recipes in full, which would surely have attracted a broader spectrum of readers from chemical circles. Boyle's view of transmutation and of composition of matter would especially deserve more attention. U. Klein (*Verbindung und Affinität*, 1994) distinguishes three basic kinds of transmutation Boyle considered. One was typical alchemical metallic transmutation: the effect of a mysterious red elixir that is mentioned in the reviewed book, with which Boyle claimed to have transmuted lead into gold. The second kind, also mentioned here, was Boyle's repetition of van Helmont's experiment with plants which should also prove that transmutation is possible, in this particular case of water into the matter of a plant. Eventually there was a third approach, not mentioned by Principe, based on Boyle's skill in chemical analysis. As pointed out by Klein, Boyle distinguished among chemical reactions on the basis of whether they can be looked upon as reversible (if we use modern terminology a bit liberally) or not. The first possibility was, for example, the synthesis of *sal ammoniac* by heating a mixture of common salt (sodium chloride) and urinous salt (ammonium carbonate). Boyle concluded that *sal ammoniac* consists of both of these ingredients as *individua*, because when he heated this salt with potassium carbonate he obtained again the urinous salt. On the other hand, the second possibility, which he considered to be the transmutation, was the reaction of *minium* (lead oxide) with acetic acid. When Boyle heated the product, the original acetic acid did not appear, but instead he obtained a quite different non-acidic liquid. To Boyle this experiment was a proof that in some cases the corpuscles of original ingredients can lose their properties and form a new unity. In reality, the first reaction yielded lead acetate that produced acetone on heating. These observations show that although Boyle was a firm adherent of alchemy, his belief contained certain 'but'. On the one hand he believed in *chrysopoiea*, on the other experiments like that with *sal ammoniac* led him to incorrect, yet chemical, conclusions.

His firm belief in *chrysopoeia* would be surprising in light of these facts if it were not supported from an unexpected side: according to Boyle, possession of the Philosopher's Stone makes it possible to communicate with angels and rational spirits. This claim yields an explanation as to why alchemists could get over the loss of financial gain: it was compensated on the spiritual level. Second, this attitude is a reflection of the religious influence that accompanied alchemy over its entire existence. This science was considered to be a gift of God, who solely decided whether an adept will reach the secrets of the Great Art. Religious men

such as Boyle could not avoid this aspect of a science he studied so thoroughly. In Principe's opinion there could even be considered a seventeenth-century English school of supernatural alchemy. If more material on this topic would be collected, it would be an interesting observation of a unique feature of English alchemy. The alchemical sources from Central Europe repeat the motif of alchemy as *donum dei* and pose various questions concerning religious problems. As late as 1730 J.K. Creiling asked whether transmutation of metals into gold is a sin, because, according to the *Old Testament*, everything done by God was already good. Therefore, there was no need to improve what was already good in the eyes of God himself; and doing so could be considered as an act against God. The idea of communication with spirits was not a common theme of Central European alchemy in the 17th century, but maybe in the England of Boyle's days it still could be a distant echo of John Dee's voice.

After reading Principe's book the question arises, who was actually Robert Boyle? Was he chemist, alchemist, religious dreamer, or mystic? The stony monument of this man breaks apart and a very complicated person appears on its place. The answer to the previous question is as difficult as any serious attempt to understand this prominent figure of science. It is perhaps better to conclude that Boyle was a product of his time. He was, nonetheless, an extraordinary product that was in some directions well ahead of his contemporaries, while in others he still clung to the gradually degrading world of his alchemical predecessors. Principe's deep analysis of Boyle's alchemical world brings up new material hitherto unknown, and this material makes it possible to draw a portrait of this scientist in much clearer contours. This book will be a 'must' to anybody who wants to study not only Boyle, but the history of alchemy and chemistry in general, and of the 17th century in particular.

Vladimír Karpenko:
Dep. of Physical and Macromolecular Chemistry, Charles University, Albertov 2030, 128 40 Prague 2, Czech Republic;
karpenko@prfdec.natur.cuni.cz