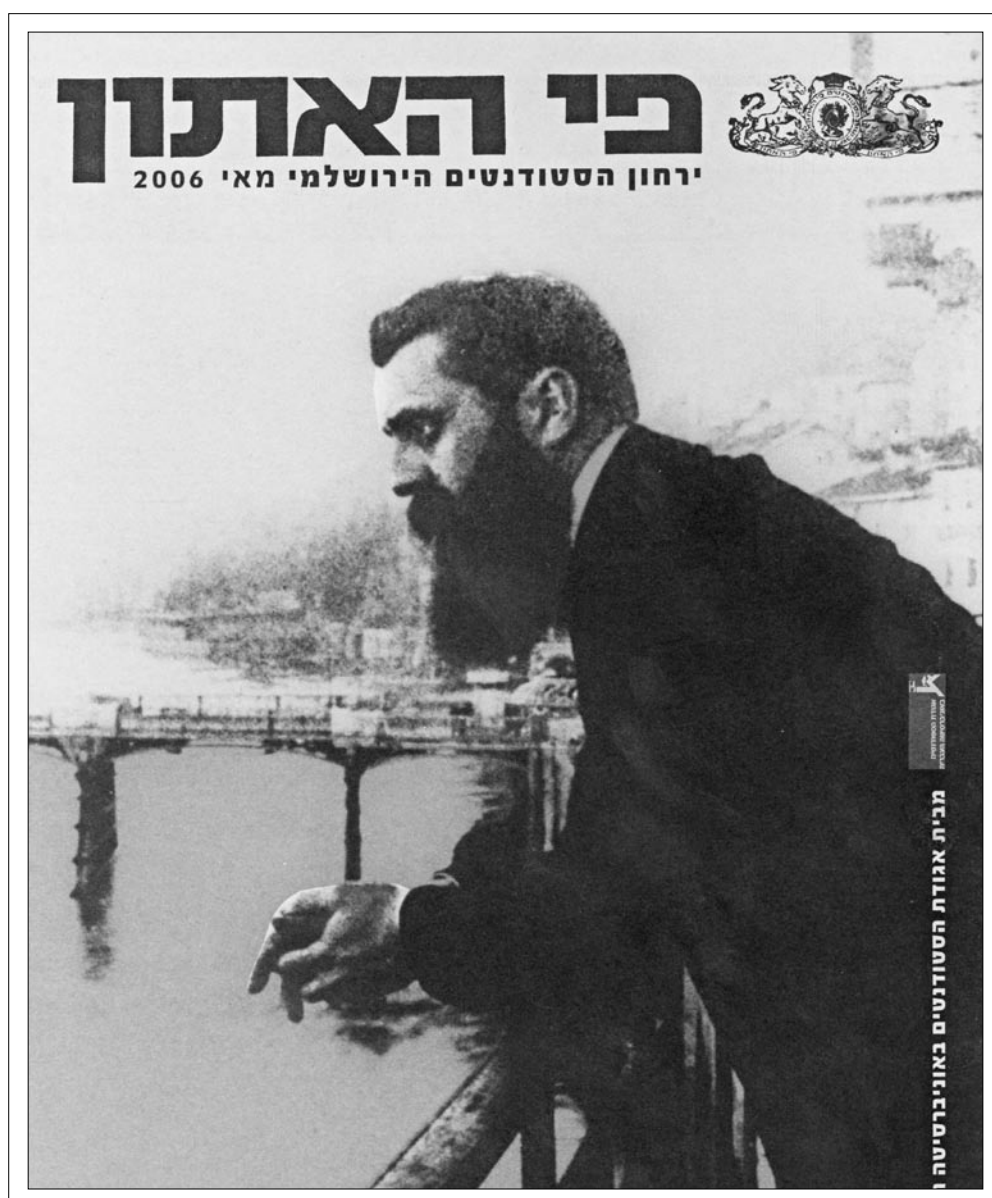


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The Cover...Theodor Herzl, 1901. See p 2.

2007 EDELSTEIN AWARD PAPER

WHAT A WONDERFUL EMPIRE IS THE ORGANIC CHEMISTRY*

Anthony S. Travis, Edelstein Center Hebrew University/Leo Baeck Institute London.

Introduction

The synthetic dye industry is the exemplar of all research-based industries. Moreover, it fostered the great achievements in nineteenth-century academic and industrial organic chemistry. During the past quarter century its history, particularly in Europe, has been the focus of an ever-growing body of historical literature, often drawing on the late nineteenth-century reminiscences of participants and reports of observers (1). While the latter invariably celebrated the remarkable status that the dye industry once held, and the industry's hold on historians of science and technology remains so tenacious, its inner workings are often little understood. This provides a reason to brush aside norms of historical accounts, particularly of detailed events that are of scientific and technical complexity, and revisit past visions and seemingly unrelated disciplines and ideologies in order to offer a slightly different perspective.

The selected impressions are in themselves of great historical interest, since they relate to a specific and pivotal era in the transformation of science, technology, and organization in industrial society. Through analogy,

contrast, and comparisons, they not only tell us what the history of the dye industry was and is all about, but say much about the shaping of modern life. They also allow us to reexamine preconceptions that have been

unconsciously borrowed from the writings of the contemporary participants and observers that, for all their failings as true objective accounts, are the foundations without which writing history might be very difficult. Perhaps in the end, the most enduring legacies of the synthetic dye industry, however it is approached, are the fascination that it continues to exert on historians and its role as the predecessor of the modern pharmaceutical and life sciences industries.



Anthony S. Travis

Inevitably, the rapid creation of a wealth of ideas, scientific and technological, also contributed to ideas that shifted political thought. Accordingly, this account begins with the unlikeliest contributor, Theodor Herzl, founder of political Zionism and enthusiast for technology. In common with a large proportion of the inhabitants of modern cities before 1900, he came directly into contact with these novel and ubiquitous products of organic synthesis, the artificial textile colorants, in his case on the boulevards of Vienna and Paris. Privileged by his own perspective,

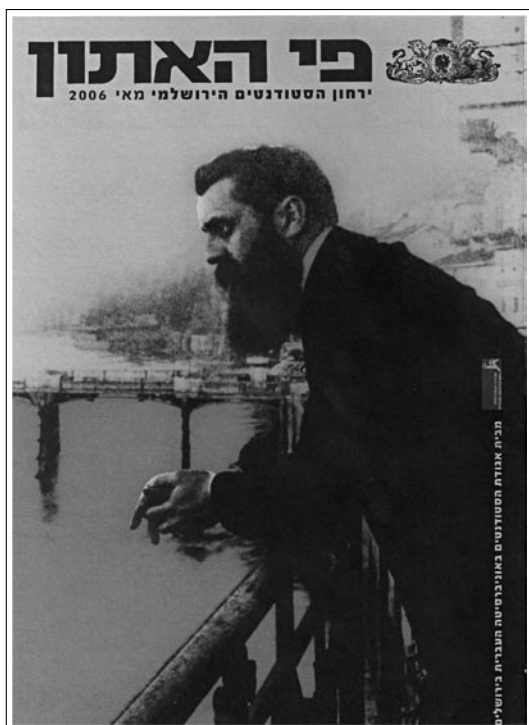


Figure 1. Theodor Herzl on the balcony of the Three Kings Hotel, Basel, in December 1901. From a photograph by Ephraim Moses Lilien. Edelstein Collection.

Herzl drew up a fictionalized account of the impact of the synthetic dye factories before 1900 that paralleled his own political transformation.

Theodor Herzl and Organic Chemistry

In late December 1901, on the occasion of the fifth Zionist Congress, held in Basel, Switzerland, Theodor Herzl was photographed on a balcony at the rear of the city's fashionable Three Kings Hotel. It is the most enduring image of the congress, recorded by the talented artist Ephraim Moses Lilien. Herzl is looking across the fast-flowing River Rhine on a broad curve that directs it toward the borders with Germany and France. The photograph, appropriately, conjures up the image of a messianic figure, or at least a great leader, perhaps contemplating internal dissent among the Zionists, or engrossed in the latest version of his futuristic utopian book *Altneuland* (completed in 1902). To this day the brooding profile serves as an ideological political statement, particularly when (from the 1909 congress) the river has been masked out and replaced by Jerusalem's Tower of David (2).

Had Lilien taken the photograph from the opposite end of the balcony, looking downstream on the Rhine instead of upstream, the background would have included the chimneys of the Basel aniline dye factories, CIBA, Geigy, and Sandoz, all located next to the Rhine. The Swiss dye industry was second only to that of Germany, whose BASF and Bayer factories were also situated on the Rhine, at Ludwigshafen and Leverkusen, respectively. These firms, mostly founded in the 1860s, transformed the waste of the coal-gas lighting industry, the black oil known as coal tar, into spectacular and wondrous colorants for the textile industry, and in some cases into medicinal products, such as Sandoz's anitipyrin and Bayer's aspirin (both introduced in 1899). Even if the Basel coal-tar dye factories did not appeal to Lilien as a suitable background for the photograph, it is likely that Herzl, now at the height of fame, had at some point glanced to the left to admire them.

Perhaps their riverside settings and belching chimneys reminded him of how dye-making factories inspired his short story, "The Aniline Inn," which first appeared in Vienna's *Neue Freie Presse* in May 1896, not long after he had published *Der Judenstaat* (*The Jewish State*). "The Aniline Inn" is an allegorical account, nothing less than a biographical reflection of how during the mid-1890s the Viennese journalist and philosopher Theodor Herzl underwent an inner transformation that would change the direction of his life. Here is a summary (3):

A professor of philosophy, a quiet man who is most at home with his books, is unhappy with married life,



Figure 2. Basel with the River Rhine, looking downstream, in 2000. The Three Kings Hotel is at the extreme left, just beyond the first bridge. The former dye-making factories are in the distance. Now merged as Novartis they are, on the right bank, CIBA and Geigy, and on the left, Sandoz. A. S. Travis.



Figure 3. This English inn, *The Black Horse*, at Greenford Green, northwest of London, might well be described as the first aniline inn. In 1857 the lady licensee of *The Black Horse* allowed William Perkin and family to erect an aniline dye factory on vacant land at the rear, next to the Grand Junction Canal. A. S. Travis.

because it interferes with his professional work. One evening, he goes out for a walk with the intention of ending his life. For a moment he has second thoughts, when he realizes that his post will be taken by a colleague whom he despises. But even that cannot dissuade the professor. He makes his way toward a point on the curve of a fast-flowing river, called the “last bank,” that is well known as a place of suicides. Next to the river is a large factory with tall chimneys, which he could not remember from earlier occasions, and nearby a small building that had certainly not been there before. In the flickering light of a lantern he glances at the sign outside the latter. It reads “The Aniline Inn.” Thus it is apparent that the factory is engaged in the manufacture of aniline dyestuffs.

Seated by the river is a man who engages the professor in conversation and announces that he fishes for people.

The professor asks: “Where do you take them?”

The seated man answers: “I’ll tell you after you have given me your life.”

The professor responds “My Life!”

“Yes, you were just about to throw it away.”

The seated man suggests that on this night the professor “donate his life” and if not satisfied with the outcome, the water of the river will still be there, waiting for him, the following day.

“Come into my inn!”

The professor: “Who are you?”

“I am the innkeeper of Aniline,” is the answer. They enter the inn, where there is a smell of coal tar. The innkeeper asks the professor: “Do you know what aniline oil is made from? The smell of tar comes from my laboratory. I distill myself . . . I do this for my own pleasure.” The professor, noticing that the innkeeper

is a large, tall, robust man in working clothes, is intrigued: “If you give me a glass of wine and show me your laboratory, then we’ll get better acquainted.” The innkeeper agrees and explains that he also has wine in his laboratory.

They pass through iron doors to a part of the inn that has the appearance of an alchemist’s laboratory. It is filled with retorts, elaborate glassware, some holding bubbling liquids, furnaces, and strange smells. One part is more like an artist’s corner, with books, pictures, bronze and marble statuettes, silk carpets, weapons, and flowers. The landlord places a bottle of Rhine wine on a table and invites the professor to pour out a glass. The professor starts to look around more closely, noticing a copy of *La Gioconda* (Mona Lisa) of Leonardo, and an old weathered gravestone with a Latin inscription (4). Then he goes to the place where the innkeeper busies himself, chasing steam through the viscous liquid to distil a light oil. The innkeeper explains: “We are no longer in the time of the sorcerer. What a wonderful empire is the organic chemistry.” [“Welch ein Wunderreich ist die organische Chemie.”]

The professor asks impatiently: “What are you? Fisherman, innkeeper, alchemist?” There is no direct response, except that in the innkeeper’s opinion the alchemists were mean people, plebeian dreamers interested only in gold. He looks for something else, not gold but bread. He foresees a savior, a chemist—and perhaps Herzl is here alluding, for the benefit of his readers, to the New Testament—a chemist who will perform a miracle and provide bread for the masses. This “inventor of the (synthetic) grains of wheat does not yet exist; maybe it will take a century. Whoever achieves this will change the whole world.”

The innkeeper explains that once he was wealthy but bored with life, and one day had also intended to commit suicide. It was the evening when he arrived at the last bank, just as workers were leaving the dye factory. He engaged in conversation with one of them, and was told that in the factory coal-tar wastes were processed in a way that had not been possible in former times, when gas works threw away the tar. Some even paid to have the foul-smelling sediment removed. But then a method was discovered (alluding of course to the work of William Perkin) for processing the tar. And now from the unwanted material various useful and valuable products are obtained. Aniline is just one of these products. The wealthy man learns from this account that just like the chemical transition from waste material to “beautiful, radiant colors,” in a similar way people can turn their

despair into high achievement. So, instead of wasting his life he built his house of aniline, as a symbol of hope.

It is an epiphany, and certainly a revelation, for the professor sees that even from discarded waste there can be obtained much that is good and useful. And so it is with the journalist Theodor Herzl, now destined to adapt his prior literary life and philosophical gleanings to the needs of the vast discarded waste of the oppressed Jewish people. This “refuse of human society” is, just like a waste product containing valuable chemicals, waiting to be processed and given purpose in the *Judenstaat*. In Herzl’s account colorant manufacture served as the proxy—and inspiration—for social engineering. The end product was the regenerated Jew. Most likely, Herzl had borrowed from Mark and Matthew in the New Testament when he assigned the innkeeper a fisher of men whose purpose was to bring about the salvation of lost souls.

Apart from what he had seen on the streets and read, where did Herzl get the idea of using coal-tar dyes for his short story? Of course, as a professional journalist he was always on the lookout for topics that would attract the attention of his readers, and at the same time put over a subtle message. Articles on this first research-based industry were widely read; the industry’s products were displayed prominently at the vast and influential world fairs; and, in the German-speaking world at least, investors were enjoying excellent returns. It is little wonder then that Herzl was attracted to the remarkable colorants made from waste. This is a striking example of how in the past the coal-tar or synthetic dye industry aroused emotions of wonder, fear, and respect. Herzl’s use of the dye industry, if unusual, was certainly not unique in its appeal to philosophical, social, and political imaginations. Like others of his generation Herzl had been excited by scientific and technological developments, particularly in the mid-1890s, when the industrial synthesis of indigo was about to be perfected. The new technology that extended the range of brightly colored printed cottons and dyed fabrics was a powerful attraction, awaiting interpretation.

Chemical synthesis had, on the one hand, replicated

nature, in the form of artificial alizarin, and on the other created entirely new products, effectively reinventing and replacing traditional items. It represented an epic struggle replete with compelling and heroic characters within a larger narrative of what was invariably seen as technical progress.

Modern historians often overlook the significance of the alizarin synthesis, preferring, instead, to linger on the 1856 discovery of mauve by William Perkin and the introduction of artificial indigo four decades later. However, there is no doubt that artificial alizarin and incremental improvements to alizarin processes made between 1869 and 1873 represent one of the crowning achievements of nineteenth-century science and technology. In 1874, for example, the *Journal of the Society of Arts* reported that while aniline dye production was increasing, it “is almost put in the shade by the gigantic development of the trade in artificial alizarin” (5). The main protagonist in this endeavor was Heinrich Caro, the unrivalled hero of nineteenth-century chemical industry.

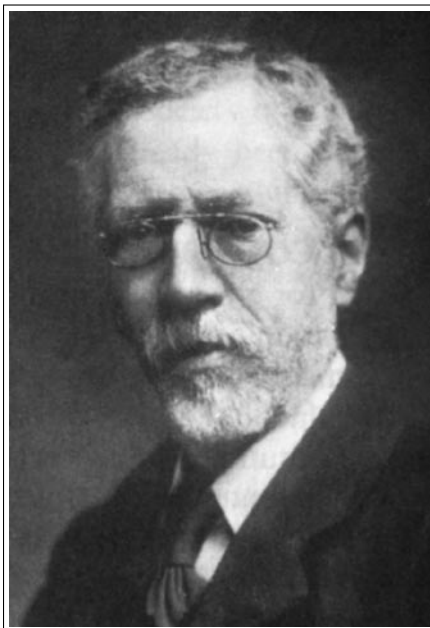


Figure 4. Heinrich Caro (1836-1910). BASF Corporate Archives, Ludwigshafen/Rhein.

Heinrich Caro

Heinrich Caro (1836-1910) received his technical education in Berlin during the early 1850s at the *Gewerbeakademie* and by attending courses in chemistry at the university. In 1855 he became an apprentice colorist at a calico, or cotton, printing factory in Mülheim, in the Ruhr Valley. His skills in practical textile coloration impressed his employers, who in 1857 sent him to Manchester to investigate the latest developments in textile printing and the machinery and chemicals employed in allied processes. This included the production of natural alizarin extracts from the root of the madder plant. In 1859 Caro returned to Manchester and joined the firm of Roberts, Dale & Co., which supplied natural dyes and chemicals to textile manufacturers. Caro discovered a new route to the mauve dye that William Perkin had stumbled upon in 1856, as well as a black colorant that was extracted from the residue of his mauve process. Caro also investigated all the new coal-tar dye processes. His understandings of the special needs of dye users and his after-sales service enabled Caro to promote and sell the novel products of his employer and bring about extensive usage of artificial

dyes. This he put to good use when he returned to Germany late in 1866, and especially after he joined BASF in the fall of 1868 (6).

Though Caro is best known for his work on the synthesis of artificial alizarin and his technical leadership as research director at BASF, he was also responsible for significant technology transfer from Britain to Germany, and he initiated the steps leading to the commercial manufacture of indigo. The indigo program was in many ways driven by anticipatory knowledge, in which prediction was founded upon firm scientific principles, as also demonstrated in the field of azo dyes. Caro's own indigo synthesis, though not a commercial success, aroused considerable scientific interest around 1880; and samples of the intermediates and of his other inventions were displayed at the 1885 London International Inventions Exhibition by BASF, the company "with which the name of Heinrich Caro will always be connected." Caro's own introduction to the display noted "[s]ome of the chemicals ... have been discovered by our chemists, others were the result of scientific research, whilst we have more or less successfully tried to render them commercially available" (7). Many, as both defensive and imitative strategies, were responses to a German rival's challenge, real or potential. The emphasis was clearly on both the science and the methods for commercializing it. In the mid-1880s, there was an inexhaustible market for colorants, or so it seemed.

Caro retired from BASF at the end of 1889, at a time when the sense for history and national pride among German chemists revealed itself in grand and sometimes even spectacular events, such as the 25th anniversary of Kekulé's benzene [Benzol] ring theory held in Berlin during March 1890. Parsimonious yet powerful, the 1865 theory of the six-membered benzene ring was totally consistent with the behavior of aromatic mol-

ecules. It quickly laid the foundations for the academic studies that fostered an industry of coal-tar colors.

Heinrich Caro contributed to the celebration in 1891 with his own epic narrative of the dye industry. It was and remains the most complete history of the industry during its formative years. Caro began writing in the late 1880s, building on earlier accounts, and probably on the exhaustive literature reviews undertaken during preparations for patent litigation in London and elsewhere. Versions of Caro's history were sprung, invariably quite unexpectedly and at great length, upon his visitors. Ernest Francis Ehrhardt, Caro's English assistant, described his first exposure to Caro's history at the latter's home in Mannheim (8):

It was, and I suppose still is, a social custom over there for the new recruits on the staff to call on the older men, and these calls were paid between the hours of 11 and 1 on Sunday morning. I promptly paid my duty call on Dr. Caro. Instead of letting me go at the end of the regulation 10 minutes he kept me until he was fetched to [lunch] and insisted on taking me with him. He kept me the whole afternoon; we went for a walk and returned, he kept me for the evening meal, and for the whole of the evening until past midnight filled the time with practically a monologue on the history of the dye industry and his experiences in connexion with it. He made this most interesting to me and he thoroughly enjoyed talking in this way himself and pressed me to come again, and repeatedly my morning calls ended only at midnight.

In order to give coherence to this great rambling and highly complex subject, Caro created a fictional German dyestuff manufacturer, a fusion of the leading firms, BASF, Hoechst, Bayer, and AGFA. He had chosen a successful approach to making a magnificent scientific and technological adventure accessible. Eschewing the

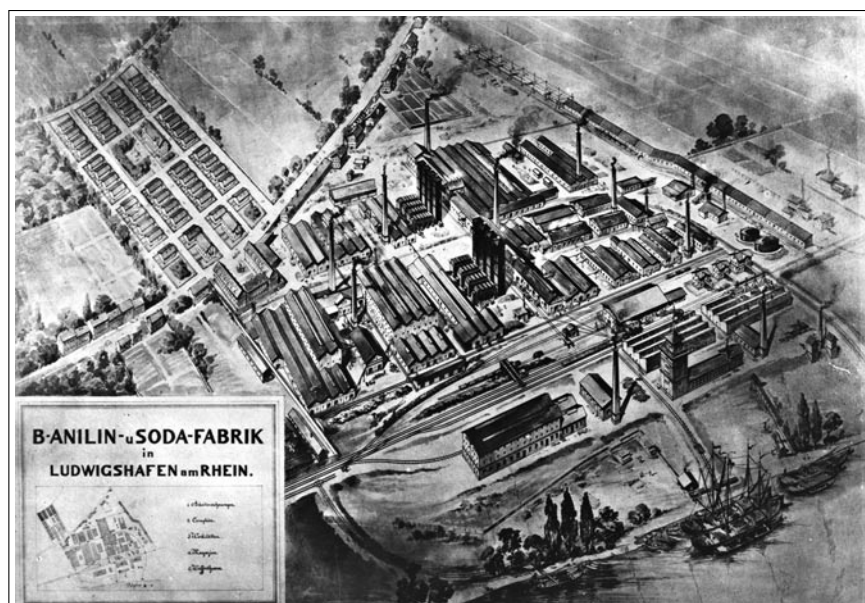


Figure 5. BASF factory, Ludwigshafen, around 1890. Edelstein Collection.

usual language of chemistry, Caro opened with a gripping account of industrial and academic origins by dramatizing the ingenuity and fecundity of coal-tar chemists. Consider the scene. His audience is taken on a tour through the sprawling factory. Caro provides a guide, who explains the historical development through the structure of the firm, most particularly the technical departments for the production of inorganic chemicals, organic intermediates, dyestuffs, pharmaceuticals, perfumes, and explosives. Dye manufacture is by its nature a collective enterprise. As the guide pauses at each department he describes its origins, formation, and development (9):

He points at the tall chimney stacks of a huge factory. "There"—he says—"are the workshops of the 'Deutsche Theerproducten-Industrie.' I want to take you there. The factory unites all branches and workshops of this industry. It employs thousands of labourers and hundreds of chemists, engineers, and managers. Its services, achievements, and performance are the pinnacles of our time. Its market is the world.

Caro went on to summarize the success of the German dyestuff industry by alluding to a biological analogy, and to a vision of a natural order, the division of labor. There was more than a hint of the newly emerging social sciences (10):

The reasons for the success of industry, which is still developing, were, according to the guide, the penetration of science into the finest veins of manufacturing practice, the continuous contact with new inventions, the progress of theoretical and applied chemistry, its responsiveness to the changing needs of the market, a strict division of labor, and a planned and harmonious cooperation of all involved, from the first to the last, everybody at his place.

Though Caro's approach to recent history was brilliant, it was dictated by his own system of values and was not entirely objective. After all, he had his own reputation to consider, particularly regarding matters of priority over inventions in which he had been involved. Undoubtedly there were biases and vested interests to consider. Moreover, while the technical facts were important at that point in time, they are less so now. It is hardly relevant that he did not deal with questions that are more interesting to modern historians. What is significant is that his approach began to give meaning to a diversity of facts.

Caro's role as an inventor and originator of industrial research was in many ways grounded in his own history, and justifiably so. Certainly his fame in the 1890s continued to spread far and wide after he left BASF, including across the Atlantic, where in 1898 the chemist Edward S. Johnson of Avalon, Pennsylvania, informed

Caro that his "scientific and technical achievements in the industries of the coal-tar colors have made him the most eminent figure in the general development of the greatest of chemical industries, and a main factor in the establishment and growth of the Badische Anilin- u. Sodafabrik" (11). Maybe Caro had in part been motivated to write his history in order to secure his own legacy, a career that extended back over three decades, following his frustrations and dissatisfactions in dealings with the management at BASF. Certainly he created a valuable story that we have been enabled to rework to suit our own theses.

Raphael Meldola

While Herzl used the dye industry for the purpose of drawing up an allegorical account, and Caro resorted to an imaginative, factual, and celebratory history, the English chemist Raphael Meldola (1849-1915) drew on the notion of survival of the fittest to articulate his own interpretation. Meldola also put together a thorough and well-researched history, with a powerful message, and

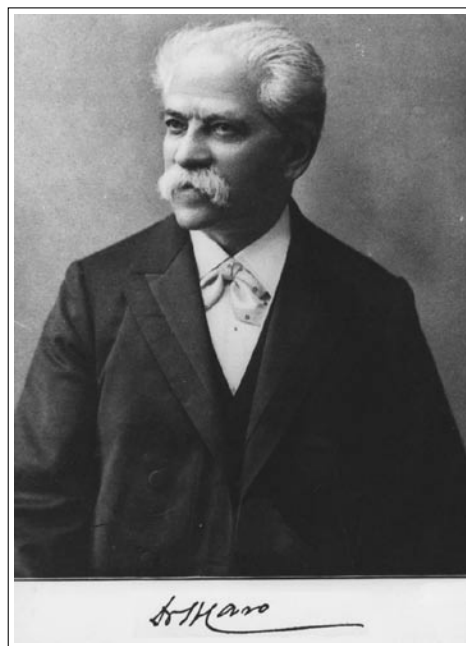


Figure 6. Raphael Meldola (1849-1915.)
Edelstein Collection.

an agenda to suit his own concerns over the neglect of technical education (12). Meldola's perspective emerged mainly out of his second period of employment in the dye industry. His employer, Brooke, Simpson & Spiller of London, showed a marked disinterest in protecting inventions. This reinforced Meldola's concerns about

the poor showing of the dye industry in Britain as users of colorants turned increasingly to German-made products. This is why in an 1886 lecture before the applied chemistry and physics division of the Society of Arts he gave “a much more forcible idea of the true state of the coal-tar colour industry in this country than hitherto has been attempted” (13). It was presented as archetypal of the development of all science-based industries. And it was, moreover, framed within the wider debate of perceived industrial decline in Britain. That was certainly true of the dye industry, as production and other figures supplied to Meldola by Heinrich Caro and by British dye users had confirmed. The statistics were stark. The approach, as we shall see, inspired Heinrich Caro’s writing of history.

Meldola adopted explicitly social Darwinist terms, particularly “survival of the fittest,” from the newly organized scientific discipline of biology. It is of interest to consider how this came about. Meldola was one of the leading proponents of the application of Darwinism to natural orders. Around 1870, just over a decade after Charles Darwin’s *On the Origin of Species* appeared in print, Meldola joined the avant-garde of evolutionary theory. His connection came from the fact that while still in his teens, in addition to studying chemistry, he developed what was to become an enduring love of nature, inspired by the Victorian penchant for collecting and classifying insects and flowers. Meldola’s principal activity, as an amateur naturalist, with particular reference to moths and butterflies, introduced him to the serious study of entomology (14).

Meldola first declared himself a “Darwinian” in the journal *Land and Water* during February 1871, observing: “Natural selection acts only and solely for the good of the being” (15). In May, also in *Land and Water*, he observed that “wonderful facts ... are perfectly intelligible on Darwin’s theory of the survival of the fittest” (16). The phrase “survival of the fittest” had in fact first been coined by the railway engineer-turned-biologist-turned-social philosopher Herbert Spencer in his 1864 book, *Principles of Biology* (17). Darwin adopted it in the 1869 edition of *The Origin*. After Meldola first joined the dye industry in 1871, he soon found that, as in nature, proof of success is that which reproduces its own kind. Darwinian thought was equally applicable to the synthetic dye industry, which, incidentally, both William Perkin and Meldola left in 1873 as Germany emerged as the main manufacturing nation.

Though Meldola would later re-enter the industry, he now joined the Royal School of Mines, where he had

studied chemistry in the 1860s. The post as assistant provided opportunities for broadening his interests, as well as for honing his skills as a writer, particularly through contact with the founder-editor of *Nature*, the amateur astronomer Norman Lockyer. For editorial assistance, Lockyer drew on the literary and scientific talents of students and assistants at the Royal School of Mines, including Meldola, who in 1874 was appointed a sub-editor. The connection with *Nature* ensured that Meldola was later called upon as a regular contributor in matters related to chemistry, natural history and other topics, including solar eclipses.

Meldola returned to the dye industry in 1877, at Brooke, Simpson & Spiller. Among his most important discoveries there was Meldola’s blue, though it was better appreciated in Germany than in England. In 1885 Meldola left the dye industry and took up an appointment as professor of chemistry at the Central Technical College, Finsbury, north London.

Despite differences of opinion, Meldola held Herbert Spencer in high regard. It was Spencer, some of whose ideas on evolution preceded those of Darwin, who extended his own theory to psychology and sociology and is credited with the development of social Darwinism (18). As well as dealing with the “cooperation” between past and present, Spencer had a special interest in cooperation between altruism and self interest in human activity. In 1884, in the postscript to his book *The Man Versus the State*, he applied his “survival of the fittest” concept to argue for industrial progress based on a “militant-type society” that flourished best without government interference. It was made relevant to the “industrial form of organization,” in which industrial competition and the pursuit of profit would eventually replace militarism (19). Industrial progress in the 1880s was based firmly on iron, steel, and, most critically, coal, the source of aromatic, or coal-tar, chemicals. There was no better example than the synthetic dye industry, at least as far as Meldola was concerned. He was soon using “survival of the fittest” as an effective metaphor when delineating the mode of rapid, successful development of chemical industry in Germany and the mode of deterioration in Britain (20).

Maybe the analogy was inspired in part by the remarkable BASF display at the 1885 inventions exhibition. Meldola was among the English chemists who requested showcase samples from Heinrich Caro after the exhibition had closed. Meldola explained to Caro that he wanted specimens for teaching purposes and for the Society of Arts lecture, in which he intended to focus on Caro’s products and their roles in bringing about a con-

vergence between science and technology. Meldola made known to Caro that he had recently left the dye industry “so that there need be no fear of any specimens which you may send being used for trade purposes” (21).

Caro was flattered at the great compliment paid to him and his firm. Meldola’s lecture was an opportunity for a British chemist to endorse the products of Ludwigshafen before an important public audience. Meldola’s choice of BASF and Caro’s inventions as a feature of his lecture was certainly deliberate, since he announced, during his lecture, presented on May 13, 1886, that more than 80 percent of coal-tar dyes consumed in Britain, the largest dye-using nation in Europe, were made in Germany. One reason why this had happened so rapidly was because English and Scottish firms had been introduced to Heinrich Caro’s products while he was working in Manchester in the 1860s.

Caro not only commercialized synthetic alizarin (1869), but, as Meldola pointed out, was fully or partly responsible for eosin (1874), the azo dye chrysoidine (1875), methylene blue (1877), the production of rosaniline (triphenylmethane) dyes by condensations with phosgene, and, with Adolf Baeyer, had collaborated on the structure and synthesis of indigo, which though not commercially successful was a “triumph of synthetical chemistry.”

Meldola showed how the German synthetic dye industry, which relied on research, had displaced its main rival, Britain, where improvisation was the guide (22):

[My] chronological record comprises nearly all the chief colouring matters from coal-tar which are or have been of industrial value. It is important to note that the list, even as it stands in the form of a bold statement of facts in chemical history, reveals the existence of that fundamental law of the “survival of the fittest.” Old products have been displaced by newer ones, as fresh discoveries were made, or processes improved.... The moral conveyed to the manufacturer is sufficiently obvious—we must realise the fact that no existing process is final, and that no product at present sent into the market is destined to survive for an unlimited period.

According to Meldola, the dye industry was (22):

...fraught with meaning both scientifically and educationally. In taking up this subject it has not been my desire to exalt the coal-tar colour industry to a position of undue importance, nor do I wish it to be inferred that the remarks which I have made concerning its decadence, or at any rate stagnation, in this country are applicable to this manufacture only.

Meldola opined that it was the “want of technical education” among chemical manufacturers that had brought this situation about. As for “rumours” of manufacturers who had no time for science, Meldola, never far from Spencerian language, declared: “As a species he is, however, doomed to extinction in the struggle with his competitors” (23).

The fact that German production of synthetic dyes was some six times that of all the English firms must have alarmed the audience. The revelation certainly provoked the Society of Dyers and Colourists to print the lecture in its own journal (24). A version also appeared in *Nature*. For his convincing description of the decline of Britain’s dye industry, alternating between the shocking, if not brutal, and the motivational, Meldola was rewarded with the 1886 silver medal of the Society of Arts. Caro was highly impressed with his approach, writing (25):

Having already read some sensational extracts of your address in the Manchester papers, I was naturally anxious to become acquainted with the entire contents of your elaborate and instructive work. Now since I have read and reread your paper I cannot but congratulate you at the successful manner with which you have solved the difficult problem of rendering new and attractive to the general public the well known topic of coal tar industry. I quite admire the method which you have adopted of illustrating by means of one, well chosen example the principal agents which have been at work to produce the immense variety of startling facts in the chemistry of coal-tar colours. Your method ought to be oftener employed by public lecturers. It is certainly more satisfactory to the audience to be substantially fed by one bit of sound knowledge, than to get bewildered by a long list of chemical names and historical facts. I shall try to become a docile pupil of yours, as on the first opportunity which shall offer itself to me I intend to lecture on the synthetical methods of organic chemistry, whilst explaining the successive phases of some special investigation interesting to the public. The example which you have so admirably commented upon, the research into the structural arrangement of the flavaniline and chrysianiline molecules, is certainly a highly instructive one. It forcibly points to the necessity of a thorough training in chemistry. The beautiful results of Otto Fischer would never have been achieved by anyone who did not command a similar knowledge of the entire range both of facts and methods accumulated by previous investigators.

Where Meldola saw faults, through a dire analysis of German dye-strength, and the need to emulate Germany, Caro saw virtues. By default, Meldola had done an excellent job in promoting German dyes. As for the

importance of technical and chemical education, Caro felt that equal, or even greater, importance should be given to the entrepreneurial spirit that was so characteristic of the pioneers, such as William Perkin, but was now generally absent.

While it is not certain that Raphael Meldola was the first to use biological analogies and the language of Darwinism to describe the state of chemical trade and formulate effective comparisons, he was the most qualified to do so through his involvement with both evolutionary thought and the synthetic dye industry. In a single lecture, a severe warning to the British, he certainly used social Darwinism with greater clarity than even Herbert Spencer.

Carl Schorlemmer

A striking example of the strong inspiration for analogy provided by the dye industry draws on the perspective of the German-born organic chemist Carl Schorlemmer (1834-1892) who, like Caro, arrived in Manchester in 1859. In the 1860s Schorlemmer was a consultant to Caro, when the latter worked in the Manchester dye industry. In 1874 Schorlemmer was appointed the first British professor of organic chemistry at Owens College (Manchester). From his close involvement in both practical and theoretical chemistry, Schorlemmer formulated philosophical views regarding how progress in science occurs; namely, that there is a direct relationship between the development of scientific ideas and their social and political contexts. This appealed greatly to Friedrich Engels, partner in a cotton and dyeing firm, with whom Schorlemmer came into close contact in Manchester (26). Engels found the chemical concepts, particularly the inner logic of chains of carbon atoms, relevant to his political writings. Moreover, he considered Schorlemmer to be the leading socialist in Europe after Karl Marx. Schorlemmer wrote a condensed though widely acclaimed history of organic chemistry, in which he offered a then novel model for the history of science that became a metaphor for later political and academic ideologies. To achieve this Schorlemmer emphasized the wider impact of the production of coal-tar products, especially alizarin and the possibility of artificial in-

digo. He thereby formulated the earliest combination of what later became known as internalist and externalist viewpoints (27). In Schorlemmer's scheme of things, the synthesis and manufacture of alizarin held a very special significance, and it was adopted in the teaching of communist ideologies until the 1980s. Through a symbolic archway draped with garlands of synthetic madder the young would commence the onward march of progress. Industrialization would bring peace and harmony (28). In contrast, in the west this approach has led to interdisciplinary understanding between the sciences and humanities.

Conclusion

Herbert Spencer in his *First Principles* wrote, "An entire history of anything must include its appearance out of the imperceptible and its disappearance into the imperceptible" (29). Despite extensive historical studies, the entire history of the synthetic dye industry, in Europe as well as in North America, has not yet been fully charted. There is, however, in the geographical sense at least, some notion of beginning and closure, since the industry emerged, at first almost imperceptibly, in Europe and now has all but disappeared from western countries. The evidence lies in the numerous brownfield sites that were once occupied by vibrant factories: ICI at Blackley, near Manchester; Holliday, at Huddersfield; GAF, at Linden, New Jersey; and Cyanamid, at Bound Brook, also New Jersey.

Their disappearances have provided a reason to explore the issues relevant to emergence, rise, and decline. In the present day it is a story that is almost forgotten, or that some wish to forget, mainly because of environmental factors, particularly river pollution and issues related to toxic intermediates (30). Note for example the low profile given to the sesquicentennial for the discovery of Perkin's mauve in 2006, when compared with the Einstein celebrations in 2005, the events marking the tercentenary of the birth of Carl Linnaeus in 2007, and the bicentenary events for the birth of Charles Darwin planned for 2009. That is perhaps all the more reason to share, mainly through some early participant histories, an appreciation of one of the great, now largely ignored, epics of the empire of organic chemistry.

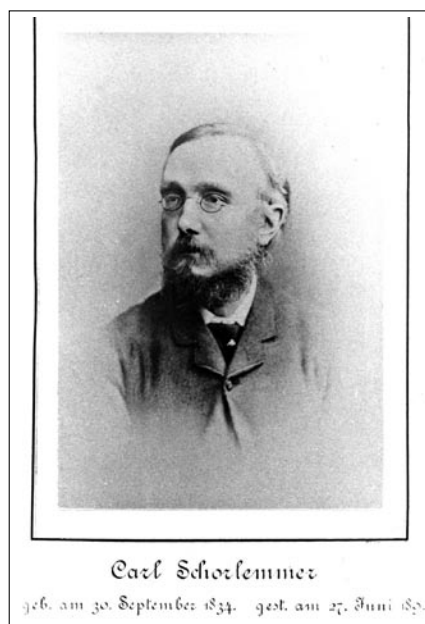


Figure 7. Carl Schorlemmer (1834-1892.)
Edelstein Collection.

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TABLE: TIMELINE FOR THE SYNTHETIC DYE INDUSTRY, 1856-1900

- 1856: William Henry Perkin in London discovers a purple aniline dye, from 1859 known as mauve. Aniline is made in two steps from coal-tar benzene.
- 1858-60: A red dye is made from commercial aniline (containing toluidines). The process is developed by French and British chemists. The colorant is known as magenta, fuchsine, etc., and in 1861 is converted into a blue dye, aniline blue.
- 1863: By substitutions into amino groups of magenta, A. Wilhelm Hofmann discovers the Hofmann's violets in May 1863. Since structural formulas are not available for aromatic chemicals, they are represented by constitutional formulas based on simple "types" of groupings of atoms.
- 1865: Friedrich August Kekulé announces his benzene ring theory. This makes it possible to draw the structural formulas of simple aromatic chemicals.
- 1868: Carl Graebe and Carl Liebermann in Berlin find that the natural product alizarin is an anthraquinone derivative of the aromatic hydrocarbon anthracene, establish the partial structure of alizarin and a route to its synthesis. This represents the first synthesis of a complex natural product in the laboratory.
- 1869: Heinrich Caro at BASF and William Perkin independently discover commercial routes to synthetic alizarin. Patents are filed in London during June 1869. Manufacture begins in England and Germany during 1869-70 and leads to the decline in cultivation of madder. This lays the foundation of modern science-based industry and industrial-academic collaboration.
- 1873: Unable to compete with the German manufacturers of synthetic alizarin, Perkin retires from industry.
- 1874: Academic chemist Adolf Baeyer, at Strasbourg, and industrial chemist Heinrich Caro, at BASF, jointly publish the modern structure of alizarin.
- 1875: Introduction of azo dyes that contain the atomic grouping $-N=N-$, based on academic and industrial research.
- 1877: Comprehensive patent law introduced in Germany, after consultation with the dye industry. It is the most advanced system in the world for protecting chemical inventions.
- 1883: Adolf Baeyer at Munich draws the modern structural formula for indigo.
- 1889: Central Research Laboratory, designed by Heinrich Caro, opens at the BASF Ludwigshafen factory. The industrial research laboratory becomes a formal business unit.
- 1897: BASF and Hoechst in Germany commence the manufacture of synthetic indigo. This leads to the collapse of the natural indigo trade.
- 1900: Germany and Switzerland are the leading dye-making countries and control most of the world market.

LETTERS OF SVANTE ARRHENIUS TO HIS FORMER CROATIAN STUDENT

Nenad Raos, Institute for Medical Research and Occupational Health, Zagreb, Croatia

Fran Bubanović (1883 – 1956), the first professor in chemistry at Zagreb University Medical School, notable Croatian textbook writer, and author of many books and articles in popular science, was one of the first postgraduate students of Svante August Arrhenius (1859 – 1927). Bubanović spent less than two years (1911/12) in Arrhenius' Nobel Institute for Physical Chemistry and published with his teacher only one paper (1), but the short stay in *Experimentalfältet* near Stockholm in the company of the best scientists of the time stimulated Bubanović to devote much of his later writing to Arrhenius and Sweden. Moreover, eleven recently discovered hand-written letters sent by Arrhenius to Bubanović between 1912 and 1916 reveal that Arrhenius and his Croatian student had a relationship that was more than just teacher-to-student, which may be attributed to their similar personalities.

At the beginning of the 20th century, Croatia had a rather peculiar political status within the Austro-Hungarian Empire, a dual monarchy consisting of eleven major nations. Franz Joseph was formally the emperor of Austria and the king of Croatia, but Croatia had actually been split between Austria (southern part) and Hungary (northern part). Despite repeated clashes between the native Croatian population and 'foreigners' (Austrians and especially Hungarians), life in major Croatian cities differed little from life in cities all over the Hapsburg Empire. In the capital of Croatia, Zagreb (which had 60,000 inhabitants at the turn of century), German was regularly spoken, but only half a century earlier Croatian

had been recognized as the official language in the Croatian Parliament. The cosmopolitan nature of the Empire is reflected by the fact that graduate study in chemistry started in Croatia when a Czech chemist Gustav Janeček (1848 – 1929) accepted an offer to teach at the Zagreb Faculty of Philosophy in 1879. Bubanović was among professor Janeček's best students, but after his graduation in 1907 Bubanović had to take a position of grammar school teacher in a small town of Bjelovar in the north of Croatia. Fortunately, thanks to the support of influential Bjelovar citizens, Bubanović received a small stipend in 1909, which enabled him to work for two years in the laboratory of Professor Hartog Jakob Hamburger (1859 – 1924) in Groningen, the Netherlands. With his Groningen professor, Bubanović published three papers (2-4), and it was also in Groningen that Bubanović made his first contacts with Svante Arrhenius (5):

As I was finishing my papers at the end of my second year in Groningen, just before the summer recess, Professor Svante Arrhenius, a Swedish physical chemist and the founder of this discipline with van't Hoff, returned from America where he stayed a while as a visiting professor (Austauschprofessor). As I still had some time of my sabbatical left and was hoping that it would be extended for another year on account of successful papers I published, I asked Arrhenius if I could come to visit his institute in Stockholm. He must have spoken about me with my teacher Hamburger, for he soon advised me that I could come at once to his institute for physical chemistry in Experimentalfältet near Stockholm. While still in Groningen, Arrhenius

delivered a lecture on physical chemistry, which gave me an opportunity to know this great man from this aspect, too.

Bubanović in Arrhenius' Laboratory

In 1905 Arrhenius retired from Stockholm University (*Högskola*) and, supported by the Academy of Sciences, decided to build a Nobel Institute for Physical Chemistry, which was completed in 1909, about two years before Bubanović became his student. Bubanović met many eminent scientists at the Institute (H. Lundén, W. Oeholm, E. Ramstedt, Lepeshkin) and was impressed by the radioisotope laboratory. What surprised the young student most was the gay and relaxed atmosphere, which at first seemed incompatible with serious scientific work (5):

Svante Arrhenius, who was then in his 55th year of life, gave the spirit and life to the Institute. His apartment was connected with the Institute by a hallway. The building lay in a park, among stones and centuries-old oak trees. The life at the institute seemed, especially in the summer, as though people were on holidays, enjoying the beauties of the countryside and of the lake, and not as though they were doing serious scientific work. I recall, for instance, that during the summer Olympic Games in Stockholm all the Institute people were sitting in the shadow of oak trees, drinking beer and waiting for hours to watch marathon runners go by.

Despite a beer or two and a good chat, the students were not deprived of the teacher's attention, according to Bubanović (5):

Arrhenius was always with us. He was constantly engaged in the scientific research of every one of us! If you met him in a tramcar or in a restaurant, he was always ready to give you a recommendation or suggestion about what you had to do, how to continue your research in order to finish your work. And everything he was doing was so spontaneous and natural. This great man was able to entirely translate his scientific thinking in one of the most complex and abstract branches of chemistry, into common discourse, and this simplicity deeply impressed people around him.

Arrhenius' "simplicity" produced unusual results (5):

At the Institute we'd organize a small colloquium in a small room every Saturday, at which we'd report on our work or on books and papers which we were asked by Arrhenius to read. Of course, Arrhenius called the tune, puffing his obligatory cigar, and here and there he'd surprise us that he forgot his own formulas and that he used such tentative phrases as 'it may well be', 'you may be right,' and so on.

Arrhenius' "forgetfulness" is also recalled in a letter dated March 28, 1913:

Ich habe mir diese grosse Mühe gegeben damit unsere Publikation (Abhandlung für Nobelinst.) wirklich begreiflich wird und es möglich wird zu finden wie Ihre Resultate berechnet sind, sonst fürchte ich wird niemand sicher sein, dass die Rechnungen nicht stark fehlerhaft sind. Also bitte ich um ganz klare Auskunft, wie Sie gerechnet haben, damit ich das in die Korrektur einführen kann.

Es ist möglich dass ich Ihre Rechnungen einmal verstanden, aber vergessen habe. Auf alle Fälle ist es doch unwahrscheinlich, dass ein Andern sie verstehen wird wenn er die Abhandlung liest. Dann wird er darauf verzichten sie weiter zu lesen. Und das wäre doch Schade (6).

Arrhenius' habit of discussing scientific topics "in a tramcar or in a restaurant" and freely mixing scientific and every day problems is also reflected in his letters. In the same letter and often in the same paragraph, Arrhenius would write about changes to be made in a manuscript, social events in his laboratory, as well as about political and family affairs. A good example is the postcard dated May 30, 1913 (Fig.):

Lieber und verehrter Herr Professor: Ich danke Ihnen herzlich für Ihren letzten Brief und gratuliere Ihnen herzlich zu den darin bevorstehenden schönen Ansichten für die Zukunft. Jetzt haben wir uns revanchiert. Meine Frau gebar heute um 12:40 U M eine Tochter, die den Namen Ester tragen wird nach einer dahingeschiedenen Liebblingschwester meiner Frau. Alles ging sehr glücklich. Maja und Esterschen ruhen jetzt nach ihren Anstrengungen aus. Im Labor ist es rechtstille. Dr Taylor reiste vor einer Woche und kommt in Juli zurück. Mr. Kendall geht nach Amerika und bleibt hier bis zum ersten Juli, wann Gardner und Lundén kommen. K. hat eine 1.200 doll. Assistentenstelle bei Alexander Smith in New York erhalten. Gardners Frau und Kinder kamen heute früh von Petersburg und wohnen im alten Haus. Frl. Dr Ramstedt ist Assistent an Lundéns Stelle.

Ich schreibe so viel ich kann um am 4 Juni für die Akademie zwei Abhandlungen fertig zu haben; es ist dann die letzte Sitzung vor den Ferien. Mit herzlichen Grüßen und Wünschen von Haus zu Haus. Ihr ganz ergebener Svante Arrhenius (7).

Despite official titling ("*Lieber und verehrter Herr Professor*") in all Arrhenius' letters, it turned out that he godfathered Bubanović's first child (letter dated March

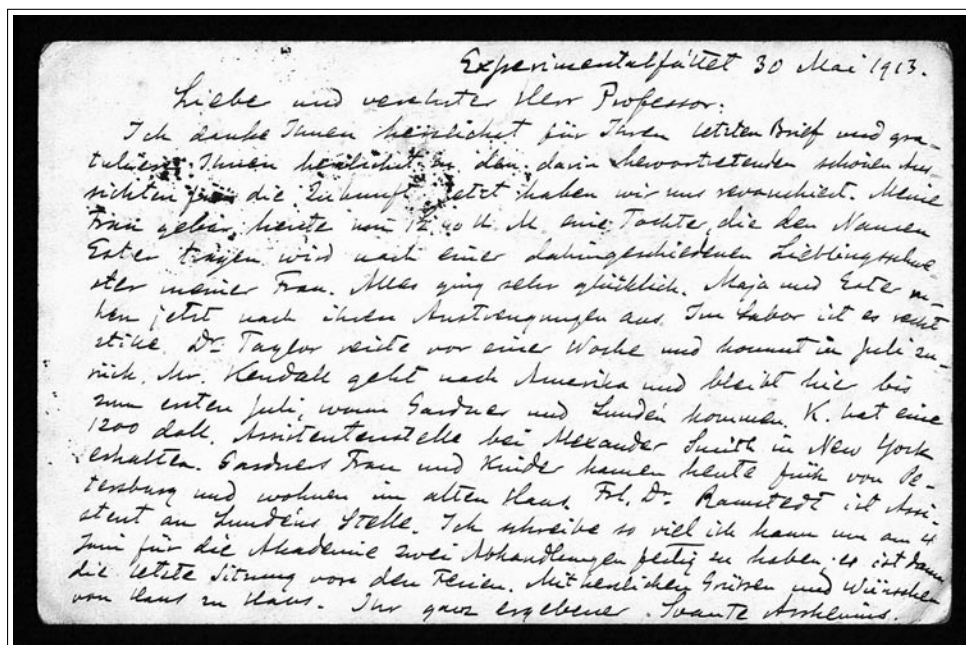


Figure. In his postcard of May 30, 1913, Arrhenius notifies Bubanović that he fathered a daughter and continues with the news from his laboratory (see text).

17, 1913); this was mentioned in the sentence “Jetzt haben wir uns revanchiert” on Arrhenius’ postcard dated May 30, 1913. The baby was born in 1913 in Stockholm and was christened Svea, a name quite uncommon in Croatia. His second child, Aleksandar was born in 1923, in a train en route from Stockholm to Zagreb (8). Bubanović married in 1911, and his wife Ivanka contributed significantly in connecting the Arrheniuses and the Bubanovićs. A letter dated December 31, 1912 describes how Ivanka, that is, “Frau Gemahlin,” brought the Arrheniuses some apples and wine produced by the Bubanovićs in the village of Gornje Vrapče, near Zagreb:

Ich hätte Ihnen längst schreiben sollen, habe aber Ihren letzten lieben Brief mit der neuen Adresse verlegt – ich hoffe doch dass dieser Brief richtig in Ihre Hände gelangt und Ihnen sowohl wie Ihrer lieben Frau Gemahlin die aller besten Wünsche zu einem erfreulichen und erfolgreichen neuen Jahr überbringt. Ausserdem soll er Ihnen unseren herrlichsten Dank für die freundlichen Weihnachtsgeschenke sagen die heute angekommen sind, nämlich die prächtigen Äpfel und die 5 Liter Wein. Diese werden vom neugierigen Zöllner geöffnet werden, so dass ich den schönen Geruch, der mir so wohlbekannt war, fühlte. Ich lasse jedoch den Wein einige Zeit stehen, da ich bei der vorigen Sendung fand, dass die Qualität dadurch sehr bald gewann (9).

Arrhenius’ Relationship with other Scientists

Bubanović first met Arrhenius in Hamburger’s laboratory in Groningen. In three letters (September 10, 1911, May 6, 1911, and July 17, 1912) mailed to Bubanović in Stockholm, Hamburger also included best wishes to Arrhenius (“Mit meinen besten Grüßen, auch an Herrn Prof. Arrhenius.”) A letter written by Arrhenius on December 20, 1913 reveals that Hamburger was Arrhenius’ host when the latter attended a physiological congress in Groningen:

Ich war in diesem Sommer zu Besuch in Groningen anlässlich des Physiologen-Kongresses. Ich und mein Schwager Prof. Johansson wohnten bei Hamburger, wo wir es ausgezeichnet hatten.

Hamburgers geben Frühstück- und Mittag-Essen für etwa 20 Personen jeden Tag während einer Woche; es muss für die Frau ausserordentlich anstrengend gewesen sein; sie blieb aber stets lustig und munter. Der Kongress verlief ganz ausgezeichnet, die Gastfreiheit und die Freundlichkeit der Groninger waren überaus grossartig. Ich wurde da u. A. mit Prof. Charles Richet bekannt, der einen äusserst sympathischen Eindruck machte (10).

The same letter reveals that, after the congress in Groningen, Arrhenius traveled to the United Kingdom where he met many colleagues and friends:

Von Groningen reiste ich nach Birmingham, wo ich eine sehr angenehme Zeit verlebte. Bei der British

Assoziation sah ich die meisten von meinen alten englischen Freunden wieder und machte ausserdem eine recht grosse Zahl von neuen Bekanntschaften unter den jüngeren Herren. Ich wohnte bei dem schwedischen Konsul, der mir eine grossartige Gastfreiheit erwies.

Von da kehrte ich über London und Gothenburg zurück und fand bei meiner Ankunft hier alles in der besten Ordnung (11).

All letters indicate close connections between the chemists of the time. At the turn of the century, chemistry had not yet been highly institutionalized, and its adepts considered themselves to belong to one big family. The center of chemistry was in central Europe (Mitteleuropa), and Germany was the premier chemical power of the world until its downfall in World War I. As a consequence, German was the standard language of all chemists. According to Wilhelm Ostwald's autobiography, it was not at all uncommon for a professor from a provincial university to spend his summer holidays visiting his colleagues on a tour around Europe (12). Arrhenius was undoubtedly among the first tier of European and international chemists, in contrast to Bubanović, who was active only in Croatia. But the optimistic and open nature of both chemists proved to be the cornerstone of their deep and abiding friendship.

Arrhenius versus Bubanović

Because of poor social conditions at that time in Croatia, Arrhenius did not greatly influence Croatian chemical research; but owing to his close personal relationship with Bubanović, he doubtless influenced substantially public awareness of science in Croatia, as well as attitudes toward Nordic people, their culture and science. Noteworthy in this respect is Bubanović's hypothesis that the people from the north of Europe are "sober and sophisticated," in contrast to the southern inhabitants, because of their high-fat diets (13). The origin of this hypothesis could be easily traced to Bubanović's investigations and interest in brain lipids (14).

In 1927 Bubanović wrote Arrhenius' obituary to be published in the Croatian (Yugoslav) (15) scientific journal *Farmaceutski Vjesnik* (Pharmaceutical Herald) (16):

If it is true that only a good man can be a great and genuine scientist, then it is personified in Svante Arrhenius. Moreover, he was an uncommonly good man! Wherever he could help, in scientific work or in life, he would do it with an impressive commitment, frankness, and openness.

These words echo in Bubanović's own obituary, written by Professor Tomislav Pinter, his successor at Zagreb University Medical School (17):

Bubanović was of a gentle nature, a man who readily helped everyone, who spared no effort to fulfill anyone's wish. It is quite unimaginable that Bubanović would decline any politely expressed wish, much less that he would do anybody, even his enemies (if there were any), any harm on purpose.

Both chemists had pronounced affinities for poetry, philosophy, and all aspects of public affairs. Both were fluent writers. It is not well known that Arrhenius, in addition to his work in chemistry, made an excursion into astronomy and was the author of both chemistry and astronomy books aimed at the general public. Bubanović, like Arrhenius, wrote about many subjects, ranging from medical and physical chemistry to philosophy and history of science. His books were very popular in Croatia among chemists as well as among laymen. It is obvious that Arrhenius served as a role model for Bubanović, who always spoke highly of his teacher (16):

He [Arrhenius] was at home not only in the scientific circles of his country, but all over the cultured world, in the same way in St Petersburg, as in New York, London, or Paris. He was among the first so-called Austauschprofessor [visiting professors] to be invited to the US. At the Sorbonne he delivered a number of lectures. He received so many honorary degrees, from the Japanese to the oldest German University, that they could hardly fit in a big wardrobe [...] He nevertheless retained a sort of classical naïve modesty in communication with people, especially with the young people who devoted themselves to chemistry, and also in all his scientific and cultural discussions and polemics. This modesty adorns all great spirits who, as Socrates put it, know that they know nothing.

The letters Arrhenius wrote to Bubanović (18), and which are now published for the first time, certainly corroborate Bubanović's eulogy of his Nordic mentor.

Scientists Mentioned in Arrhenius' Letters

James Kendall (1889 – 1978) and *Alexander Smith* (1865 – 1925) were British-American chemists notable as textbook writers. *Charles Robert Richet* (1850 – 1935) was a French physiologist awarded the Nobel Prize in Medicine and Physiology in 1913. *H. S. Taylor* was a specialist in catalysis.

ACKNOWLEDGMENT

The author wishes to thank Professor Elsa Reiner for her help with Arrhenius' letters.

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6. It took me a great deal of trouble to finally come to understand our publication (*Abhandlung für Nobelinst*) and calculations. I'm afraid no one can be positive that they are error-free. Could you explain them to me, so that I can revise them accordingly? It may well be that your calculations were clear to me earlier, but they must have slipped my mind. In any case, it is very unlikely that anyone else will be able to understand them, and this will discourage others from reading our article through. Now, that would really be a shame.
7. Dear and esteemed Professor: Thank you very much for your last letter. I congratulate you with all my heart on the lovely imminent prospects. Now we return the compliment. My wife gave birth today at 12.40 P. M. to our daughter, who will be named Ester after my wife's late favorite sister. Everything is on the right track. The troubles for Maja and baby Ester are now over. It is very quiet in the lab. Dr. Taylor left a week ago and will return in July. Mr. Kendall leaves for America, where he is to stay till July 1st, when Gardner and Lundén will return. K. got a \$1,200 assistantship with Alexander Smith in New York. Gardner's wife and children arrived from Petersburg this morning and are staying in the old house. Assistant Lundén was replaced by *Fräulein* Dr. Ramstedt. I write as much as I can in order to finish both papers for the Academy before June 4th, when the last meeting before holidays takes place. With best regards from our house to yours. Sincerely yours, Svante Arrhenius.
8. A. Bubanović, personal communication.
9. I should have written to you a long time ago, but I misplaced your last kind letter and your new address. Anyway, I hope that this letter will come into your hands and bring you and your kind wife my very best wishes for a gratifying and a successful New Year. In addition, it should convey our greatest gratitude for the kind Christmas gifts that arrived today, that is to say, for the beautiful apples and 5 L of wine. Curious customs officials must have opened it, so I could smell its beautiful bouquet, so familiar to me. However, I will shelve the wine for a while because your previous shipment proved to gain in quality with time.
10. I paid a visit to Groningen this summer on the occasion of the Physiology Congress. I and my brother-in-law Professor Johansson had wonderful accommodations with the Hamburgers. The Hamburgers provided breakfast and lunch for about 20 people every day for a week; it must have been extremely tiring for his spouse; nevertheless she was witty and cheerful all the time. The Congress went extremely well; the hospitality of the people of Groningen was exceedingly kind. I was introduced, among others, to Professor Charles Richet, whom I found awfully nice.
11. I traveled from Groningen to Birmingham where I had a wonderful time. I saw most of my old English friends of the British Association and made numerous new friends among younger gentlemen. I stayed there with the Swedish consul, who honored me with his delightful hospitality. I returned via London and Gothenburg (Göteborg). On my arrival here, I found everything in tiptop shape.
12. W. Ostwald, *Lebenslinien. Eine Selbstbiographie*, Klasik & Co. GMBH, Berlin, 1926.
13. F. Bubanović, "Nordic People and Us," *Thank you, Chemistry*, Tomo Jovanović & Vujić, Belgrade, 1939, 45-53.
14. F. Bubanović, "Untersuchungen über die Gehirnlipoide in der Oellösung, I. Mitteilung," *Liječ. Vjes.*, **1928**, 50, 835.
15. Croatia was a part of the Austro-Hungarian Empire until 1918; later it became part of the Kingdom of Yugoslavia (1918 - 1941), then a German satellite state in World War II (1941 - 1945), and the federal state of the "new" Yugoslavia, ruled by communists (1945 - 1991).
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17. T. Pinter, "Prof. Dr. Fran Bubanović (1883 - 1956)," *Croat. Chem. Acta*, **1957**, 29, 53-62.
18. Arrhenius' letters are now the private property of his son Aleksandar Bubanović, Šoštarićeva 8, HR-10000 Zagreb.

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ARSENIC, NITRATE, AND PERCHLORATE IN WATER – DANGERS, DISTRIBUTION, AND REMOVAL

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While it is generally recognized that there is a considerable amount of water on the Earth, most of it is unavailable to us. Only about 2.5% is fresh water, and a considerable fraction of that is inaccessible in the form of ice or stored in deep groundwater (1). The flows of water present an even more sobering picture because the amount of water stored in all the rivers of the world is thought to be 2,000 km³, whereas annual withdrawal of water amounts to about 3,800 km³/year (1). Water availability may be better expressed as annual discharge, 45,500 km³/year, that flows through various rivers of the seven continents to the ocean (1). Although the quantity of water is surely important, the quality of water is no less so, and this paper is concerned with the impacts of three groups of species, arsenic, nitrate, and perchlorate.

Arsenic Species

Arsenic species in groundwater have become a major worldwide problem, owing to their carcinogenic and other toxic properties. Relatively high concentrations have been reported in such countries as Argentina, Bangladesh, India, Japan, Mexico, Mongolia, Taiwan, Philippines, and the Peoples Republic of China (2-4). The Bangladesh situation is especially bad because of the very high concentrations of arsenic in the groundwater. Unfortunately, about 97% of the population drank tube well water (from hand-pump shallow wells), and nearly 85 million persons are at risk from poisoning from arsenic-contaminated water (5).

The symptoms of those adversely affected are serious: skin lesions, hyperkeratosis, melanosis, skin cancer, cancer of internal organs, and “black-foot” disease (6). In addition, serious respiratory effects can result from long-term ingestion of arsenic (7). According to one source (6), contamination of groundwater by arsenic in Bangladesh is “the largest mass poisoning of a population in history” (6). The main source of drinking water in that country, especially in the rural areas, is shallow tube wells (< 150 m deep), and this is a source of tragic irony. Bangladesh authorities tried to prevent water-borne diseases by shifting the drinking water supply from surface water to tube wells, but many of the six to ten million drinking water wells contain high concentrations of arsenic (8). According to a British Geological Survey study of 2,200 tube wells from eastern, southern, and western Bangladesh, about 21 million persons were drinking water with arsenic concentrations above the maximum allowable concentration of 50 ppb (50 µg/kg) set as the Bangladesh standard (9). As a consequence, widespread arsenicosis occurred with the possibility of enhanced cancer rates (10).

Several technologies have been presented for removal of arsenic from drinking water. These include precipitation/coprecipitation, adsorption, lime softening, ion exchange, and membrane filtration. Precipitation requires addition of an agent to produce an insoluble solid. Coprecipitation removes substances in dissolved or a colloidal state through flocculation and coagulation. Chemicals used (based on known solubilities) might

include ferric salts, ferric hydroxide, alum, ammonium sulfate, calcium hydroxide, and copper sulfate (11).

Precipitation and coprecipitation are widely used techniques, but there are challenges for arsenic removal. The problem is species-related: the presence of arsenite decreases the effectiveness of arsenic removal, and some oxidation scheme must be incorporated into the overall process (12). In addition,

ortho arsenic acid, H_3AsO_4 is a stronger acid ($K_{a1} = 2.5 \times 10^{-4}$) than meta arsenous acid, $HAsO_2$, ($K_{a1} = 6 \times 10^{-10}$) (13). This means that at pH 7, all of the ortho arsenate is ionized, 50% as $H_2AsO_4^-$ and 50% as $HAsO_4^{2-}$. In contrast, at the same pH, nearly all of the As (III) species would be present as the unionized acid, so removal of both species as precipitates would require pH adjustment.

A second problem with Bangladesh, and perhaps other locations, is cost. For rural areas where the problem is acute, the poverty level is such that a technique must be exceptionally cheap. A new approach developed at Lawrence Berkeley National Laboratory may well overcome both problems (14). The process involves coal-ash particles (1-10 μ) coated with ferric hydroxide. When arsenic-contaminated water interacted with the composite, ferric arsenate precipitated. Presumably, in very small villages, individuals would use a filter in the form of a pouch containing the composite, and water from a contaminated well could be passed through the filter into a suitable container. Laboratory samples with 2,400 ppb could be reduced to an arsenic level of 6-8 ppb. No comment was made about the presence of arsenite.

While the problems of Bangladesh drinking water have been well documented, suppliers of drinking water in the United States face problems as well. The new standard for arsenic in drinking water (10 ppb) for the United States was scheduled to begin January 23, 2006, a notable decrease from 50 ppb. It is estimated that some 4,000 water systems will be required to reduce arsenic levels in their water supplies, and of these 97% are small utilities (15). Presumably the cheapest method of treating arsenic-laden well water is dilution with arsenic-free water, but that may not be a viable option if all the wells in the area have unacceptably high levels. Accordingly, when the standard was 50 ppb, only 0.51% of all community

water systems in the United State were above the standard; with the new standard, about an estimated 6.187 % (3,034) of such systems were over the allowed level (16). Examination of the data more closely indicated that about 97% of the systems affected obtained their water supplies

from groundwater with the arsenic in the As(III) form, which would be more carcinogenic and more difficult to treat. About 60% of the affected systems

were in the "Very Small Water Systems" category providing water to fewer than 500 persons (16).

The size of the water system affects the increase in annual mean household cost for meeting the 10 ppb standard. (Table)

Table. Annual mean household cost for attaining 10 ppb As standard (16)

Utility size, Number of homes	<100	101-500	501-1000	10,000
Cost, \$	358	246	98	23

More than one mechanism is envisioned for the availability of arsenic in ground water in Bangladesh and perhaps elsewhere. The problem has been most thoroughly considered for Bangladesh because of the extremely serious nature of the contamination. One positive aspect is that the problem seemingly is not due to point-source pollution caused by humans, although that might lead to an easier treatment. For example, McArthur and co-workers (17) dismissed the possibility that competitive exchange of phosphorus in fertilizer contributes to arsenic availability. One mechanism of contamination proposed by them is the release of arsenic sorbed onto hydrous iron oxides, $FeOOH$, where it is microbially reduced (17, 18). They assert that the most intense reduction and thus the greatest source of arsenic pollution arises from microbial fermentation of buried peat. A human component is involved, however, in that microbial fermentation of organic waste from latrines could also reduce the hydrous iron (III) oxide. Sources other than peat lack the abundance or reactivity to generate the severe effects noted but could account for low-level contamination (<50 ppb).

Another mechanism addresses the mobilization in terms of which species of hydrous iron (III) oxide is involved: oxidation of pyrite versus oxyhydroxide reduction (4). Those that favor pyrite oxidation believe the arsenic contamination is anthropogenic and can be related to excessive groundwater withdrawal (4). These authors suggested that a study by the British Geological Survey was flawed and rejected the pyrite oxidation hypothesis.

The authors (4) criticized errors in the estimates of the percent of wells that were polluted.

A third mechanism involves inflow of organic carbon, which in combination with groundwater removal had drawn water from a depth where the arsenic level was a maximum (19). The combination of the two processes meant that so-called young carbon had driven recent biochemical events. Further studies indicate that field injection of molasses, nitrate, and low-arsenic water could rapidly mobilize arsenic. This raised issues of the proximity of irrigation wells to tube wells used for drinking water (19).

The US EPA Office of Research and Development has supported a four-system testing program at 40 sites in 20 states (15). The technology systems tested were coagulation-filtration, iron removal, anion exchange, and adsorption (seven media). Presumably the results of the field tests will be available in due course as will the US EPA decision.

We believe a system we have described involving an iron (III) derivative of an IMLIG (immobilized ligand), a polyethyleneamine that is chemically attached to high-surface silica, Octolig®-21/Fe(III) composite, merits consideration as a removal material on a larger scale (20). The basic IMLIG, Octolig®-21, has been used in large-scale applications in the United States and Europe for removing heavy metals (21). Converting this IMLIG to the iron (III) composite (Ferrilig) was surely a facile synthesis (21), and the resulting composite could reduce 300 ppb As (150 ppb As as arsenite and 150 ppb As as arsenate) to 3 ppb or less by column chromatography (4.5 cm id, 1780 mL of Ferrilig). The removal of arsenic in the field could be accomplished by using pre-packaged Octolig®-21/Fe(III) composite. We recognize that additional research would be needed to test what would be a suitable container: A tube? A cloth or cloth-like material used in a similar manner as suggested by Binns (14)? In addition, it would be necessary to evaluate the economics and efficacy and the inevitable differences of various matrices.

Nitrate

Nitrate is thought to be the world's most common contaminant of groundwater aquifers (22), and about 42% of the US population depends upon groundwater as its source of drinking water supply (23).

The contamination is use-based. For example, total nitrogen in streams and nitrate in groundwater are highest

in agricultural areas, according to Ward and co-workers (24), followed by urban areas and areas of mixed land use. This variation is a consequence of the alteration of the nitrogen cycle by human activity, especially over the last fifty years, leading to a significant accumulation of nitrate ions in the sources for drinking water (24). For example, human production of nitrogen currently exceeds fixed nitrogen from natural sources by some 30% (25), whereas according to Lambert and Driscoll (26), prior to 1950, human input was a small fraction of natural sources. Major input associated with human activities is due to the use of fertilizer, followed by animal and human wastes, nitrogen oxides (automobiles, trucks, buses and utilities), and leguminous crops that fix nitrogen (25).

The problem with the build up of nitrate is a consequence of the chemistry of nitrogen. Ward and co-workers (24) noted that nitrate is not taken up by plants nor by denitrifying bacteria and migrates to streams and ground waters. Under reducing conditions, nitrate can be transformed to molecular nitrogen by denitrifying organisms under oxygen-poor conditions, a significant feature of the nitrogen budget in the ocean (27). And various sources of nitrogen can be transformed to nitrate by bacterial nitrification, by hydrolysis, and mineralization in oxygen-rich conditions of soil and water.

The maximum concentration level (MCL) mandated by the US EPA for nitrate in drinking water is 10 ppm (mg/L) nitrate-nitrogen ($\text{NO}_3\text{-N}$) or 44 mg/L as nitrate (24). The World Health Organization requires a slightly higher standard, 11 ppm $\text{NO}_3\text{-N}$ or 50 ppm as nitrate (28).

The standards are provided out of concern to protect infants from "blue baby syndrome" or methemoglobinemia (24). Ingested nitrate is reduced to nitrite, which can bind to hemoglobin to form methemoglobin. Elevated levels of this substance exceeding 10% lead to the condition of methemoglobinemia, as the oxygen-carrying capacity of blood is affected, resulting in a change from a rosy complexion to the so-called "blue-baby syndrome" (24). The susceptibility of infants arises from a dual characteristic: a greater capacity to reduce nitrate to nitrite and their lower levels of a critical enzyme that converts methemoglobin back to hemoglobin (24). Nitrate can have an adverse effect on the thyroid gland, and signs of increased thyroid volumes and thyroid disorders were reported for 10-13-year-old school children in the city of Kosice, Poland (29). The children lived in a high nitrate area located in agricultural lowland with a high nitrate drinking water (51-274 ppm) supplied from shallow wells.

How widespread the contamination is depends upon the source; but one system in Florida has been well studied: nitrate contamination of spring waters in the Suwannee River Basin in northern Florida. There are some unique problems here, including agricultural factors. When the Lake Okeechobee Technical Advisory Committee reviewed the contamination of Lake Okeechobee, a major source recognized was waste from dairy cattle, and a solution was a buy-out scheme: dairy farmers were paid to take their cows elsewhere, and a number were taken to the Suwannee River basin where presumably land was cheaper. The amount of nitrogen from dairy cattle represents a small component of the total nitrogen available in the system, and only a slight impact of dairy cows seems to have been observed over the years (30, 31).

Nitrate is of potential concern because it is a precursor to *N*-nitroso compounds, a group of genotoxic substances that can be animal carcinogens (24). While nitrate ion is a relatively inert ion that is nonmetabolizable by human enzymes, nitrate-reducing bacteria can reduce nitrate to nitrite. Under the acidic conditions of the stomach, highly reactive species are formed that can react with secondary and tertiary amines to produce the *N*-nitroso amines (33). R. S. Braman, for example, found an association between nitrosamines in urine and bladder cancer (32). The relationship between intake of nitrate in drinking water and urinary nitrosamines has not been established, however (24).

Other cancer effects associated with nitrate in drinking water have been considered in various studies. Pancreatic cancer showed no significant associations with quartile populations having average nitrate intake or years of exposure (34); the conclusions were similar for colorectal cancer, except for slightly elevated risks for certain subgroups, e.g., those with above-medial meat intake (35). Ward and co-workers (36) reported dietary nitrate was associated with increased glioma (brain cancer) risk, but did not find an association with drinking water nitrate intake.

Probably adverse effects associated with drinking-water nitrates are, as noted, "the result of a complex interaction of the amount of nitrate ingested, the concomitant ingestion of nitrosating cofactors and precursors, and medical conditions of the host that may increase nitrosation" (24).

The possible association between childhood Type 1 insulin-dependent diabetes mellitus and nitrate intake has been considered in several investigations(37). One

such study covered over 1,000 cases of Type 1 diabetes in children (0-14 years old) out of over 2.8 million children (37), and the authors concluded there was no convincing evidence that drinking water at current levels in the Netherlands was a risk factor for this disorder.

Certain areas of the world have significantly high nitrate levels in drinking water. One of these is northern Punjab, Pakistan, where 16, 40, 67, and 70% of the samples in four separate districts exceeded WHO and US EPA drinking water nitrate levels (38). The authors of the study note that septic tanks, soaking pits, and solid waste dumps are common in these districts, but also excessive use of nitrate fertilizers can be a factor because of leachates from these sources combined with intensive agricultural production. High concentrations of nitrate in shallow aquifers can also be found in other areas of intense agriculture (Belgium, France, Germany, US Midwest, United Kingdom), as well as in near-desert regions, sites of heavy stresses on the water resources (39). Namibia, for example, has recorded 16 times the recommended limit of 50 mg NO₃/L (39).

It would be unwise to focus solely on one species in a source of water, a lake, for example. Senn and Hemond (40) noted the positive effects of nitrate in an urban lake (Upper Mystic Lake in Massachusetts), where they demonstrated that nitrate controlled iron speciation by oxidizing iron (II) to iron (III) to produce particles that tended to remove arsenic (V) species, also favored in the presence of sufficient nitrate ion. Thus, nitrate levels in this eutrophic lake, and perhaps many others, affected the speciation of a truly undesirable element and probably limited the recycling of arsenic to produce more soluble, more toxic species of arsenic (III).

The "Eliminate Project," whose goal is zero effluent nitrate, is in progress (39). Some 40 selected sites in the UK have used specially developed nitrate-selective ion-exchange resins. Though the drinking water is very good, the resulting effluent (brine with high nitrate concentrations) constitutes a significant disposal challenge. The Eliminate Project is an effort to develop an electrochemical means of converting the nitrate-containing brine effluent to nitrogen gas and reuse the ion-exchange regenerate (39).

One good example of this type of approach is the removal and destruction of nitrate by using water-compliant selective materials such as Purolite's A520E or Rohm & Haas' Amberlite PWA 555. These materials are regenerated with a concentration brine to regenerate the ion-exchange materials. Then the brine solution is

sent to an electrochemical cell (EDA's SERIX-systems) to produce molecular nitrogen and water (41).

Perchlorates

The problem of perchlorate contamination may be widespread. US EPA identified perchlorate users and manufacturers in 44 states and releases in 18 states and came to the conclusion that perchlorate affected the drinking water of 15 million persons in the United States (42). Perchlorates represent a comparatively recently recognized danger as a water contaminant, primarily since World War II because of the use of ammonium perchlorate as a rocket propellant. Some lesser problems associated with fertilizer application have been suspected because perchlorate can be a natural contaminant of Chilean saltpeter (43), and there is a possibility of naturally occurring perchlorates in Texas (44).

The concern for perchlorate in water supplies arises from three factors: the effect on the thyroid, high solubility of most perchlorates, and, curiously enough, improvement in the assay for perchlorate. Most commonly used perchlorates are quite soluble, so that if there is contamination through careless applications of ammonium perchlorate, the material is likely to spread and contaminate ground water. In 1997, moreover, the assay sensitivity for perchlorate in water was enhanced from 0.4 mg /L (400 ppb) to 4 µg/L (ppb) by means of a new ion chromatography method so that lower levels of perchlorate could be detected.

Presumably because of releases of ammonium perchlorate by defense contractors, military operations, and aerospace programs and enhanced analytical sensitivity, perchlorate has been found in drinking water throughout the southwestern United States (45). Public water supplies in Southern California had detectable perchlorate ion levels (5-8 ppb), and those in southern Nevada were at 5-25 ppb (46). The US EPA has recommended a provisional cleanup level for this pollutant in the range of 4-18 ppb (47).

On the other hand, industrial usage of ammonium perchlorate was not the only cause of perchlorate contamination of water supplies, as a thorough study of the Texas Southern High Plains aquifer system revealed (44). Among a total of 254 wells in nine counties over an area of about 24,000 km², 70% had detectable perchlorate (>0.5 ppb), 35% had concentration of 4 ppb or greater (44). Several possibilities were proposed: (1) a natural mineralogical contaminant, (2) agricultural fertilizers

contaminated with perchlorate, (3) in situ generation of perchlorate by redox reactions, or (4) some combination of these factors, not yet fully understood (44).

Perchlorate in drinking water is a risk for public health because of the effect on the thyroid gland. During the past 55 years, potassium perchlorate has been used to treat hyperthyroidism (46). More generally, perchlorate is a competitive inhibitor of iodide uptake. At current therapeutic levels or lower, pharmacological effects of perchlorate are ascribed to inhibition of the sodium-iodide symporter (NIS) on the thyroid follicular cell membrane. Levels of interest are those at which thyroid levels may be reduced or TSH levels increase, and such exposure may begin at the 35-100 mg/day range. The level at which perchlorate starts to affect iodine uptake in humans may occur at about 1 mg/d. The ions can affect production of metabolic hormones by the thyroid gland (43, 47), which would affect development; also, perchlorate ions can even induce thyroid gland tumors.

The concern over the possibility of cancer occurring as a result of drinking water contaminated with ammonium perchlorate has arisen. One study (48) examined the number of observed cancers versus those expected for a California community (1988-1998). No significant differences were observed between observed and expected for all cancers, for thyroid cancer, or for 11 other types of cancer, and fewer cases than expected were reported for lung and bronchus and the colon and rectum. But more cases than expected were observed for uterine cancer and skin melanoma.

Perchlorate ion is difficult to remove from water. Because it is a very soluble ion (2.09 kg/L) (49), there is no obvious technology for its removal (47). For example, while some anion-exchange resins may remove perchlorate, they remove all other anions first, and the final product water is too corrosive for use without restoration of hardness (47). Use of zerovalent metals may successfully remediate chlorinated aliphatic compounds (e.g., trichloroethylene), but they are ineffective for perchlorate (47).

Bioremediation of perchlorate-contaminated water has potential (45, 50), as bacteria capable of such degradation are widely distributed in nature in concentrations ranging from one to thousands per gram of water or wastewater, sediment, or soil (51, 52). And it may well be that bioremediation will be the penultimate solution to this challenging problem. At present, though, Logan (47) suggested that new ion-exchange systems capable of selectively removing perchlorate would be the best

solution for small amounts of contaminated water. One such system is Purolite A-530E bifunctionalized resin, which offers a high selectivity for perchlorate (53). Biodegradation has been successful even in 11% brine solutions, and biodegradation may ultimately be the most cost-effective system for treating “wide-spread contamination of drinking water” (47). The problem of perchlorate contamination is one that is likely to persist, given the contamination of aquifers, a common source of drinking water.

The ultimate answer to perchlorate contamination and related problems may be wisdom of use and disposal.

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FUTURE ACS MEETINGS

April 6-10, **2008**—New Orleans, LA
August 17-21, **2008**—Philadelphia, PA
March 22-26, **2009**—Salt Lake City, UT
August 16-20, **2009**—Washington, DC
March 21-25, **2010**—San Francisco, CA
August 22-26, **2010**—Boston, MA
March 27-31, **2011**—Anaheim, CA

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THE JOINT PAPERS OF PAUL KARRER AND ALFRED WERNER

Dean F. Martin and Barbara B. Martin, University of South Florida

At a symposium in the History of Chemistry Division in San Francisco, during an interesting paper by Professor J. S. Siegel (1), a comment was made in passing that Karrer worked for Alfred Werner for three years, but his work was never published. The comment was notable, considering what we had known of the productivity of both persons. It also seemed uncharacteristic of Werner, who was known to care for his students (2). It seems appropriate to review briefly the background of both persons before determining why the statement might or might not be correct.

Alfred Werner (1866-1919)

Werner's background is amply provided elsewhere (3-5). Briefly, it may be noted that in 1892 at the University of Zürich he was faced with producing a *Habilitations-schrift*, a requirement for a position in a German-speaking university. He awoke one night, brewed coffee, and started writing; and by the afternoon of the next day Werner had finished describing the basis of coordination theory of inorganic compounds (6). He was subsequently made a *Privatdozent* and in 1893 assumed the chair of chemistry at Zürich. An energetic mentor, he attracted an international group of students, both men and women. By 1911 he was only 45, but was "quite gray haired and very fat" (7). In 1913 he received the Nobel Prize. The onset of arteriosclerosis was evident according to Dr. Yuji Shibata (7). On October 15, 1919, Werner was forced to resign from his teaching and laboratory duties, and he died exactly one month later (8).

Paul Karrer (1889-1971)

Karrer's academic history is presented in an official summary below (9). Karrer worked with Werner from 1908-1911, received his D. phil. for a dissertation titled "Untersuchungen über Valenzisomerie beim Kobalt" (9). He served as an assistant in 1912. His postdoctoral research in chemistry with Paul Ehrlich at the Georg Speyer Haus, Frankfurt-am-Main, extended for a period of six years (10). Subsequently, he became a Reader at Zürich in 1918 and a Professor in 1919 (9, 10). He was a co-recipient of the Nobel Prize in Chemistry (1937) "for his investigations of carotenoids, flavins and Vitamins A and B₂" (10). He later was Rector at Zürich, 1950-51 (9).

What follows is the entry for Dr Karrer from the Matrikeledition of the University of Zürich (9):

• **18286** phil.II Chemie WS1908KarrerPaul*1889mTeufenthalAGCHtechn.Abt.Kts.schule Aarau (Mat. zgn.)ohne Zgn.29.06.1911 ; (prom. StAZ U 110 e.15)* 21.04.1889 , Wg. Leonhardstr. 12 bei Stähelin ; 1911 Dr.phil.II, Diss. "Untersuchungen über Valenzisomerie beim Kobalt" (J`verz.1910/11 Nr.176), 1919-59 Ordinarius f.Chemie a.d.Univ.Zürich, Rektor 1950/51, 1937 Nobelpreis, Constaffler, oo Lene Frölich (1890-1972), + 18.06.1971: UFS 1983 S.733 ; J`ber.Univ.Zch.1971/72 ; SL III 763E: Dr. Paul K` , Birkenhof, Aarau

In the view of some, Paul Karrer and Paul Pfeiffer were the only two of Werner's 200 doctoral students who really attained notable success, and Pfeiffer was the only one who remained in the field of coordination chemistry.

It is also important to note that Karrer had a high regard for Werner, about whom he remarked (4):

Alfred Werner was a model teacher. The clarity and logic of his thinking made his lectures enjoyable hours.

It seems highly unlikely that he would have had this high regard, had none of his work been published.

Plausible Reasons

There could be at least five reasons for the validity of the statement about Werner/Karrer publications.

First, Werner was very busy (5, 11). He had ten productive years, from 1893-1913, before the onset of his illness became truly debilitating. Reportedly, 52 papers were authored by him alone, and 75 were co-authored with associates (11). There was a total of 200 thesis investigations that were made under his inspiration and supervision (5).

Second, poor health would have impacted not only his productivity but his priorities as well. Accordingly, it is reasonable to assume that not every dissertation would be published.

Third, focus could have been a factor. There were two major challenges. Werner was faced with providing convincing evidence of the validity of his view of the constitution and configuration of coordination compounds over the so-called chain theory. Perhaps the most significant critic was noted Danish chemist Sophus Mads Jørgensen (1837-1914), who would not be convinced until Werner succeeded in presenting the existence of the two geometric isomers of $[(Cl_2(NH_3)_4Co)^+]$. This feat, achieved in 1907, was taken as evidence of the octahedral structure that Werner had proposed (12). A second challenge was concerned with the resolution of asymmetric cobalt complexes, a series, "Toward an Understanding of the Asymmetric Cobalt Atom," and a

dozen papers on this topic appeared in *Berichte* between 1911 and 1914 (13, 14).

Fourth, the pattern of authorship varies among researchers. Our mentor, the late Dr. W. Conard Fernelius, believed whoever wrote the first draft of a paper became the senior author, and this was true of the five papers that we, between us, co-authored with Fernelius.

Werner followed a different course in publication. He was senior author on most if not all his papers, and he was either the sole author or appeared to be in many other publications. But he would give credit in an interesting way to those who had done the experimental work. The American Victor L. King was the codiscoverer of optically active coordination compounds in 1911; yet the first paper in the series (13) shows Werner as the sole author on the title page (p 1887).

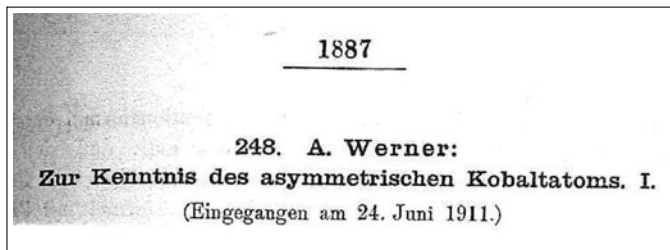
On page 1890, under the experimental section (Experimenteller Teil), he gives credit "von V. L. King" to his experimental colleague (see below).

This pattern is one that we have observed in more than one of Werner's "solo" papers; but the point remains, unless one examines all of the solo papers, one could miss a "joint paper," i.e., one in which Paul Karrer appears as an active participant, one that we would regard as a joint effort.

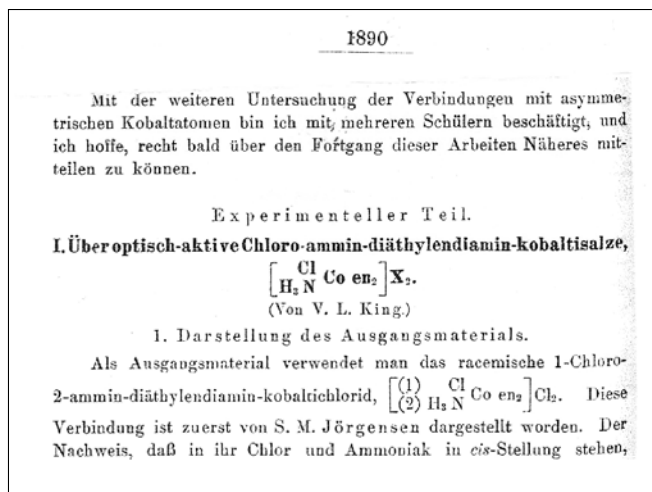
Fifth, delayed publication is a plausible reason that Karrer's dissertation would not have appeared, owing to the onset of Werner's terminal illness.

Success, perhaps

We did in fact find reference to joint publications, or in fairness, other persons did. Karrer (14) provided an obituary of Werner that included a bibliography described



Portion of title page from Ref. 13

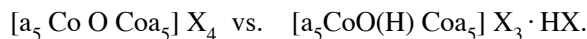


Portion of page from p 1890 of Ref. 13

as “extensive but not complete” (11). F. R. Morral (11) provided a list of papers by Werner, which includes one coauthored by Karrer (published in 1918) and a posthumous publication by Werner with J. E. Schwyzer and “P. Karrer” (published in 1921). The first paper (15) provides proof that Karrer’s work with Werner was, in fact, published. The second paper (16) contains a misprint, as the third author listed is “Walter Karrer” on the actual opening page.

When Werner became seriously ill in 1915, his academic activities were taken over by Paul Pfeiffer and Paul Karrer (17), who assisted Werner upon his return from Frankfurt to the University of Zürich.

There is, however, a matter of interpretation. One may note that the paper cited (15) is an example of *ligand isomerism*, i.e., the nitric oxide molecule could potentially coordinate through N or O. Karrer’s dissertation appears to be on a different subject, “Untersuchungen über Valenzisomerie beim Kobalt” (9). Valence isomerism refers to the fact that the two isomers differ with respect to an atom inside vs. outside the coordination sphere. A good example would be the two compounds below (a refers to a unidentate ligand, e.g. NH₃):



Up to this point, we have not found a paper that specifically refers to this type of isomerism, and it was not listed in the examples of isomerism cited by Morgan (3).

We did, however, find reference to a joint paper involving Werner and P. Karrer (15) and to one co-authored by Schwyzer and “W.” Karrer (16). We also found that Karrer was respectful of Werner in Karrer’s writings, and that he was a dedicated friend and colleague. We should like to think that we have corrected a misunderstanding in an otherwise fascinating presentation.

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ADVANCES IN 13th CENTURY GLASS MANUFACTURING AND THEIR EFFECT ON CHEMICAL PROGRESS

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Introduction

The technology of glass production is thought to have been known since ~2500 BC (1-3) and had become fairly advanced within the Roman Empire (4). At that time glass was widely used for blown vessels, pitchers, beakers, bowls, and other tableware, with such glass objects becoming as widespread as pottery (1-3,5). The use of glass for laboratory apparatus, however, was rather limited because of a lack of durability under rapid temperature changes and poor chemical resistance. For example, the combination of poor quality and the thick, irregular nature of the glass resulted in the frequent breaking of the vessels during distillation (6).

With the collapse of the Roman Empire, glass production declined for a time as glassmakers moved either into the East or to the outer regions of the old empire (1, 3). These glassmakers, however, not only preserved many of the Roman glassmaking techniques, but also began developing new patterns and styles. One such glassmaking center flourished in Venice and Murano (Fig. 1) during the 13th through 16th centuries (1, 3, 7), and it was here that improved glass was produced beginning in the second half of the 13th century (3, 4, 8). The strength of the Venetian glass made it especially practical for glass vessels, and its high melting point made it useful for laboratory apparatus (1). The glass industry received great impetus from the growing general use of glass for chemical vessels. At the same time, the flourishing industry at Venice and Murano greatly influenced chemical

progress (5, 7). The ability to produce more laboratory apparatus and vessels from glass allowed much greater freedom and versatility in their design; no matter what shape was needed, it could be made of glass. Additionally, pieces of glass could be melted together, forming a seal without cement. It is difficult to imagine modern chemistry without glass apparatus.

The goal of this study is to attempt to bring together various partial works in history, chemistry, and glass studies in order to give for the first time a detailed picture of how and why the Venetian glass of the 13th century

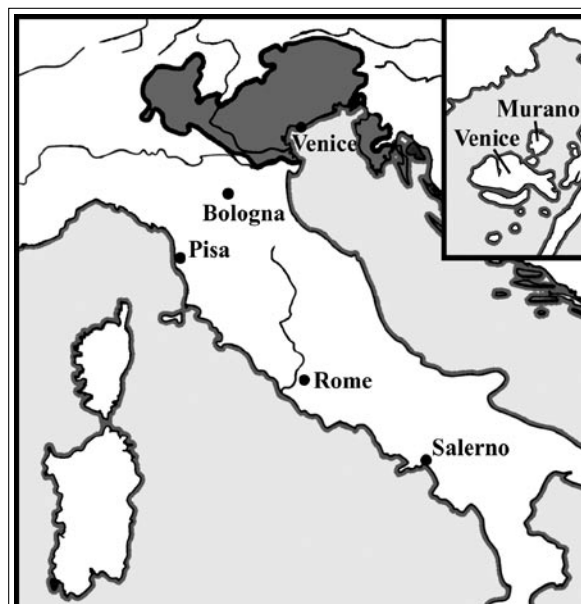


Figure 1. The Venetian territory of the 14th century (9)

became suitable for use in chemical apparatus and what effect this new glass had on the progress of laboratory practitioners. For example, it could be argued that this improved glass technology led to the invention of eyeglasses and a vast improvement in still design, both of which occurred shortly after the introduction of the improved glass and within close geographical proximity to Venice. As a result of better stills, important materials were isolated in pure forms for the first time, most notably alcohol and the mineral acids. The availability of these materials then greatly changed the evolving fields of both chemistry and medicine.

The Composition of Medieval Glass

The majority of medieval glasses adhered rather closely to a formula consisting of three primary components: silica, lime, and an alkali, typically either potash (K_2CO_3) or soda (Na_2CO_3) (10-12). The alkali is used to reduce the rather high melting point of the silica ($\sim 1710^\circ C$) to below $1000^\circ C$ (10). The addition of calcium salts can result in an even greater reduction than alkali alone, resulting in the lowest temperature of the triple eutectic at $\sim 725^\circ C$ and giving a typical soda-lime glass of the composition 21.3% Na_2O , 5.2% CaO , and 73.5% SiO_2 (10).

The importance of lime, however, was not initially recognized and it was not intentionally added as a major constituent before the end of the 17th century (2, 11-13). Prior to that time, all lime content in the medieval glasses was a result of impurities in either the silica or alkali source. Until the beginning of the 14th century, the nearly exclusive source of silica used by the Venetian glassmakers was various Sicilian sands (13). These sands are thought to have provided also considerable alumina, as well as iron oxide, lime, magnesia, and frequently small amounts of manganese (2, 8). These sands were gradually replaced with quartz pebbles ($\sim 98\%$ silica), which reduced impurities that contributed to coloring of the glass (iron, chromium, etc.) (13-15). The two primary sources of alkali were *natron*, a natural sodium sesquicarbonate ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$) found in Egypt and Syria, and various types of plant ash (2, 12-17). The actual composition of *natron*, however, often varied widely because of chloride and sulfate impurities (12, 14, 15). As one might imagine, the composition of plant ash could be even more complex and variable. In addition to providing sodium and potassium carbonates, plant ash often furnished sodium and potassium chlorides and sulfates, as well as calcium and magnesium salts of carbonate and phosphate (8, 12-14, 18). These calcium

salts would then be converted to lime during the fusion processes. Thus, the actual composition of medieval glasses depended heavily on both the specific raw materials and how those materials were treated prior to use.

As discussed above, the source of silica could affect the resulting glass composition. It could be argued, however, that the largest difference between the glass compositions of the previous Roman period and the improved Venetian material was due to the source of alkali. Most Roman glasses were prepared with *natron* as the alkali of choice (2, 18). The Venetians, however, favored the use of plant ashes, in particular the ashes from the salt marsh plant *salsola kali*, which were imported from the Levant (modern Syria, Libya, and Egypt) (8, 12-16, 18). These Levantine ashes, called *allume catino* (19), were used almost exclusively in Murano until the end of the 1600s (16). During this time their use was even protected by the Venetian government, and the use of other plant ashes for glassmaking was expressly prohibited (13, 16). *Allume catino* had relatively high soda content (up to 30%), as well as quite large amounts of calcium and magnesium carbonates (8, 12-14, 16, 18), but the exact source of the ash could also play a factor in its composition. For example, the ash of Syria was regarded to be better than that of Egypt, as the Syrian ash was blacker in color because of its higher carbon content (14). It has been proposed that Venice's close economic ties to the Levant, including access to Syrian glass technology and craftsmen, greatly influenced Venetian glassmaking and thus resulted in a blending of the plant ash-based methods of the Levant with the previous Roman methods (3, 4, 18).

In addition to *allume catino*, the Venetian glassmakers also utilized *barilla* or Spanish ash, obtained from the burning of marine plants (*salsola sativa*, *halogeton sativus*, *salsola kali*, and *suaeda maritima*) from the salt marshes of Alicante, Spain and other parts of the Mediterranean (14, 17). The highest quality *barilla* for glassmaking was called *agua azul*, of which Alicante was the sole source (17). The source of this form of *barilla* was described as a shrub with blue green berries, thought to be *salsola sativa*, which gave this particular *barilla* ash a blue color (14, 17). Like *allume catino*, *barilla* was a soda-rich ash (up to 30%) containing significant quantities of calcium salts (12, 15). While it is believed that both the Levantine and some *barilla* ashes may have been derived from *salsola kali*, it is important to note that plant ash composition depended largely on the soil in which the plants grew. This is best illustrated by the fact that plants grown in salty soil or near the sea produced ash high in soda, while those grown inland gave ash with

higher potash content (2). As a result, the Levantine and *barilla* ashes may have been similar, but distinct, raw materials, with *allume catino* being the initial and preferred material and *barilla* becoming more common by the 16th century (12). Neri later wrote of both materials, also expressing a preference for the Levantine ash over *barilla* (20). This preference was due to the fact that glass from *barilla* would tend to suffer from some light blue coloring (14, 17, 20), which has been proposed to be a result of iron oxide content in the ash (14).

Another significant contribution to the advancement of the Venetian methods was the introduction of new processes for the preparation of the alkali raw materials. The plant ash (either *barilla* or *allume catino*) was shipped to Venice as hard pieces of calcined residue. Although these chunks of calcined residue then required pulverization after arrival, it was preferred over ash that arrived in powdered form (8, 13, 16). The pulverized ash was then purified by a series of sieving, filtering, and/or recrystallization steps, which could remove unwanted impurities and result in an alkali source with a more consistent composition.

The Effect of Composition on Physical Properties

While the typical soda-lime glass composition of 21.3% Na₂O, 5.2% CaO, and 73.5% SiO₂ can give a low melting material that is easy to work with, it does not have sufficient chemical durability to be practical. Additionally, laboratory glassware must often withstand severe temperature changes in the presence of strong reagents. Hence, for laboratory glassware to be useful, it must not only be resistant to chemical attack, but must also be durable under thermal stress.

The low chemical durability of typical soda-lime glasses is largely due to the high sodium oxide content (10, 21). Decreasing soda and increasing lime content can overcome this problem, but this defeats the purpose by increasing the tendency toward devitrification (i.e. glass crystallization resulting in frosting and loss of transparency). This, however, can be corrected by the addition of further oxides such as magnesium oxide (10).

It has been shown that replacing sodium content with either lime or magnesium results in increased resistance to attack by acidic or basic solutions (21, 22). In fact, lime or magnesium oxide content as low as 3% results in significant increases in chemical resistance. Additional

magnesium content shows a slight advantage over lime for improved water and acid resistance, but lime imparts a markedly improved resistance to alkaline solutions in comparison to magnesium.

The second critical property for laboratory glassware, its thermal durability, is also dependent on chemical composition. Like most solids, glass undergoes thermal expansion that can result in increased stress during rapid temperature changes. For simple soda glasses, the thermal expansion actually increases with soda content, thus resulting in glasses with low thermal durability and a tendency to break under rapid heating. Substitution of sodium oxide by another oxide results in decreased thermal expansion with increased content of the new oxide. Both magnesium and calcium oxides, discussed above, result in significantly decreased thermal expansion, with the addition of magnesium oxide providing the greatest effect (23).

The preparation and purification methods employed by the Venetian glassmakers ensured raw materials with a more consistent composition, resulting in the production of a more consistent and uniform glass. However, the use of the Levantine and *barilla* ashes over *natron* may have played as great a role in the improvements in glass. As shown in the Table, Venetian glass samples dated to the 11th-14th century (samples B-D) exhibit considerably higher calcium and magnesium content by comparison to earlier Italian glass of the 9th-10th century (sample A) (2, 13). While the dating of samples B-D is somewhat broad, the time span does encompass the period believed to have resulted in the marked improvement in glass technology (i.e. the later 13th century) (3, 4, 8), and the changes in the composition of these later samples are consistent with the discussed improvements. In addition, it is reasonable to argue that the higher content of these elements is due to the use of the Levantine or *barilla* ashes that are known to contain significant amounts of calcium and/or magnesium (8, 12-15, 18). The higher content of these oxides would therefore result in a material that exhibited both higher chemical durability and less thermal expansion (10, 21-23). This new glass would therefore be more resistant to the action of water, acids, and bases, and would be less affected by rapid temperature changes, thus making it ideal for use in laboratory glassware. The introduction of this improved glass then paved the way for new and improved applications of its use. It has been argued that the development of both lenses and laboratory glassware was a result of these Venetian advancements (24).

Table. Chemical composition of Italian glass samples from the 9th-10th and 11th-14th centuries

Content (wt %)	Glass Sample ^a			
	A	B	C	D
SiO ₂	77.8	68.5	68.6	70.0
Al ₂ O ₃	2.2	1.95	1.40	1.90
Na ₂ O	6.4	12.5	12.5	11.7
K ₂ O	8.7	3.00	2.90	1.45
CaO	2.1	8.20	9.05	11.9
MgO	0.7	2.70	3.05	1.15
Fe ₂ O ₃	0.8	0.47	0.38	0.30

^aA: 9th-10th century (Ref. 2); B-D: 11th-14th century (Ref. 13)

Spectacles

While the specific inventor of eyeglasses is unknown, available evidence points towards their development shortly after 1286, most likely in Pisa, and their use spread rapidly throughout Europe (24-29). The production of eyeglasses was facilitated by the glassmakers' mastery of the making of uniform, clear glass necessary for a good supply of quality lenses, and it has been speculated that the original inventor was most likely an experienced glass worker (25-27). By 1300, eyeglasses were being produced by Venetian glassmakers and were repeatedly referenced in guild regulations during the first two decades of the 14th century (25-27). In fact, Venice became such an important center for the production of eyeglasses that Venetian spectacle makers left the existing glassmakers' guild to form their own guild in 1320 (26). While glassworks and the production of eyeglasses became established in other regions, the glass of Murano was considered to be of superior quality and a more suitable substance for the grinding of quality lenses. Therefore, Murano glass continued to be imported into these regions even after independent glassworks had been established (26).

The earliest spectacles were comprised of two separate lenses and frames, held together with a rivet (26, 29). These spectacles utilized convex lenses (24, 27, 28), thus improving vision for the farsighted and were used primarily for reading (26, 29). Concave lenses, for the nearsighted, were more difficult to work and did not arrive until the mid-15th century (24, 27-29). Without eyeglasses, people born with poor vision would be illiterate or have insufficient vision for a skilled trade. Even most people with normal vision typically lose the ability

to focus after the age of 40 (24). Thus, eyeglasses, which nearly double the intellectual life span of the average person, affected the progress not only of chemistry, but science and technology in general.

Stills and Alcohol

The ability to use glass in the production of laboratory apparatus allowed much greater freedom and versatility in design, and nowhere was this more evident than in the rapid evolution of the still. The still, thought to have been the earliest specifically chemical instrument, dates back to the end of the first century (30-32). As shown in Fig. 2, the traditional form of the still consisted of three components: the distillation vessel (*cucurbit*), the still head (*ambix*) with an attached delivery tube (*solen*), and the receiving vessel (*bikos*). The term *ambix* was later transformed through the addition of the Arabic article (*al-*) to become *alembic*, and by the Middle Ages the term *alembic* was used to refer to the still as a whole (6, 30-32).

The early stills were made from a mixture of primarily earthenware (with the interior glazed) and copper, although sometimes glass receiving vessels were used (6, 30, 31). As glass industries evolved, it

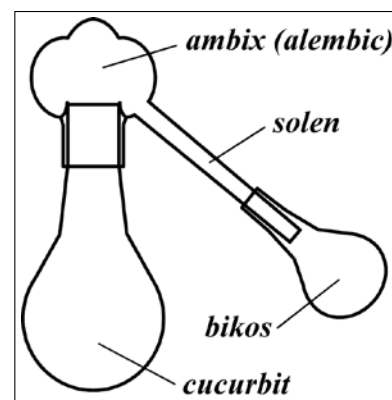


Figure 2. Various components of the early still.

became more common to use glass for first the *alembic* and then later for both the *cucurbit* and *alembic* (6). One of the difficulties encountered with the use of glass in still components was the breaking of the vessels because the glass was typically thick, irregular, and of poor quality. To counter this, a thick coating (up to two or three fingers) of clay was applied to the exterior of the *cucurbit* (6). This helped reduce breaking, but the poor heat transmission of the coating resulted in unnecessarily long preheating periods, thus making it difficult to distill volatile liquids such as alcohol.

Evidence clearly shows that alcohol was discovered ~1100 AD, most likely at the School of Salerno, the site of an important medical school (33-37). The reason for the late discovery of alcohol was partly due to the long preheating period coupled with inefficient cooling.

However, another factor was that even the most refined alcoholic distillate separated by the early stills contained so much water that it would not burn, thus making it difficult to differentiate from normal water (34-36).

Initial efforts to improve cooling methods were to cool the delivery tube (*solen*) with wet sponges or rags. As the delivery tube was now typically cooler than the *alembic*, condensation occurred primarily in the delivery tube. Because of this, the typical medieval *alembic* no longer contained an inner rim for collecting the condensate within the still head. As glass components became more common, more versatile approaches to cooling were investigated. These ideas culminated in the “wormcooler” or cooling coil, which led the cooling tube through a tub of water for more efficient cooling of the delivery tube, as shown in Fig. 3 (38). This idea was introduced in the late 13th century in the writing of Taddeo Alderotti of Florence (Thaddeus Florentinus, 1223-1303) of the University of Bologna. By use of a “canale serpentinum” run through a cooling trough and a regular supply of fresh cooling water, it is thought that it was possible for Thaddeus to obtain easily 90% alcohol after multiple fractional distillations (36, 38).

The impact of the glass industry on still evolution was evident by the move away from earthenware still components to all glass stills, which were eventually blown or cast in one piece. This new type of distilling

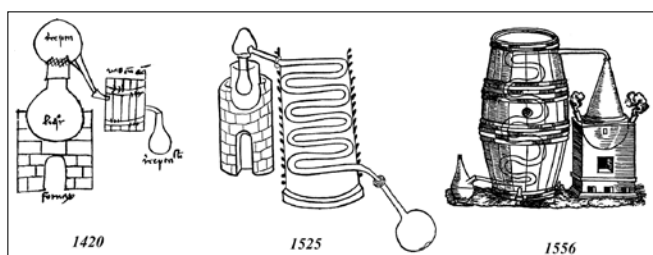


Figure 3. 15th and 16th century woodcuts illustrating the “wormcooler” cooling coil (Ref. 5, 37).

apparatus was called the *retort* (from Latin *retortus*, “bent back”) as shown in Fig. 4 (6). More importantly, later 16th-century authors such as Hieronymus Brunschwyck (1450-1512) and Conrad Gesner (1516-1565) specified not only glass distillation components, but preferably those of Venice (39, 40). Brunschwyck even stated that the distillation vessels (40):

...must be made of venys [Venetian] glasse bycause they shoulde the better withstande the hete of the fyre.

From such writings it was clear that specialists in Venice and Murano designed and made specific glass apparatus for the practicing alchemist and artisan. The use of such apparatus then made the isolation of alcohol routine, so that it could become a common reagent of the laboratory.

The primary importance of alcohol to chemical pursuits was its use as a powerful solvent. Not only could it solubilize most salts and other water-soluble substances, but it also dissolved many organic materials not soluble in water, such as fats, resins, and essential oils. This

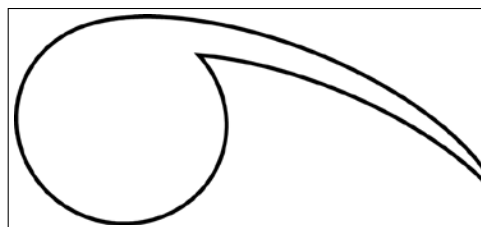


Figure 4. The retort.

greatly expanded the number of possible useful solutions available to the practicing alchemist and provided the first liquid known that could be used to extract the volatile aromatic substances from plants (38, 41). At the same time, alcohol began to be used as a medicine in the mid-13th century, two Italian physicians, Vitalis de Furno (ca. 1260-1327) and Thaddeus Florentinus, being the first who are known to have applied it in this way (34). It was reasoned that purified alcohol would in turn purify the patient from illness and by 1288, alcohol as a medicine was in general use. Its effect on the human organism was obvious and its effect on the failing powers of the aged led to its use as a medicine against old age. Its power of preserving organic matter from putrefaction probably also helped support the idea that it would preserve the human body. The belief that alcohol was the *quintessence* gave reason for the presumption that it would prove to be the most perfect of medicines (41). In a more practical sense, washing wounds with alcohol cleansed them and killed some microorganisms. In addition, administering alcohol to the patients made them relaxed, comfortable, perhaps even happy, thus allowing the body a chance to heal itself (37). By the mid 14th century, the medicinal and preservative properties of pure alcohol became the backbone of the writings of such authors as John of Rupescissa, and it was soon widely recommended as a universal remedy (36, 38).

Mineral Acids

While earlier practitioners were well acquainted with the vitriols (i.e. metal sulfates) and their calcination products, the acid vapors had not been condensed prior to the 13th century. It has been suggested that the newly formulated retort may have been important in the preparation of the mineral acids, as its one-piece design would have been beneficial for such corrosive compounds (35). Without doubt, glass or other still materials used for such isolations required good chemical resistance, which may have been the factor limiting an earlier discovery.

Nitric acid was prepared by the dry distillation of mixtures of saltpeter (KNO_3) with either alum ($\text{NH}_4\text{Al}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$) or sal ammoniac (NH_4Cl). The resulting acidic vapors would condense in the still head along with adventitious water, thus producing aqueous nitric acid solutions. This acid was soon produced in large quantities as a sideline of the saltpeter industry; and by the 15th century Venice had become a center for its large-scale manufacture (35, 42).

Sulfuric acid (oil of vitriol) was prepared by first "roasting" or calcining vitriol (usually green vitriol or hydrated FeSO_4) in an earthen vessel to produce a crude mixture of metal oxide and sulfuric acid. The mixture was then distilled in a glass retort to isolate the desired acid solution. Alternately, sulfuric acid solutions were also made by burning sulfur under a glass bell and dissolving the resulting vapors in water (35, 42).

Although the preparation of hydrochloric acid seems to have occurred at a later date and was not commonly used until the 17th century, the use of nitric and sulfuric acid reagents quickly changed the laboratory setting. Access to these acid solutions allowed practitioners to dissolve metals and most ores either at room temperature or in a water bath. This removed the need for enormous furnaces in special workshops, since glass vessels at workbenches were now sufficient for many processes. Entirely new classes of room temperature reactions were now possible, and there was an enormous increase in the number of people who could do laboratory work, thus greatly accelerating the rate of progress in chemical technology.

Conclusion

A combination of the calcium and magnesium content of the alkalis utilized and the purification of those materials to maintain consistent properties allowed the

glassmakers of Venice and Murano to produce superior glasses beginning in the 13th century. The quality of the Venetian glasses dominated the European glass-making industry until the 18th century and had a direct impact on the advancement of the chemical sciences. The ability to produce more laboratory apparatus and vessels from glass allowed much greater freedom and versatility in the design of chemical laboratory ware, especially a vast improvement in stills. As a result of better stills, important materials were isolated in pure forms for the first time, most importantly alcohol and the mineral acids. The availability of these materials then greatly changed the evolving fields of both chemistry and medicine and marked the beginning of a new stage in the history of chemistry.

ACKNOWLEDGMENTS

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THE LESSER KNOWN CHEMIST-COMPOSERS, PAST AND PRESENT *

Leopold May, The Catholic University of America

The most prominent chemist-composer was Alexandre P. Borodin (1833-1887), organic chemist, about whom much has been written (1). The chemistry and music of another chemist-composer, Lejaren A. Hiller, Jr., (1924-1994), polymer chemist, have been the subject of several publications (2). In addition to Borodin and Hiller, there were four previous chemist-composers, George Berg, amateur chemist-composer, Sir Edward W. Elgar, amateur chemist-composer, Georges Urbain, inorganic chemist-composer, and Emil Votoček, organic chemist-composer. There are also three contemporary chemist-composers, E. L. Bearer and Morris Kates, both biochemists, and Carlo Botteghi, industrial chemist. Their chemistry, music, and short biographies will be presented.

Previous Chemist-Composers

George Berg, Amateur Chemist-Composer (~1720-1775) (3-5)

Although the exact date is not known, George (or Georg) Berg was born about 1720 and as some sources suggest in Germany. He was an organist and a teacher of violin and harpsichord. At the Ranelagh Gardens in the late 1750s he probably played either the organ or the violin. He was elected a member of the Royal Society of Musicians in 1763, and was listed in Thomas Mortimer's *The Universal Director* as 'composer & teacher on the harpsichord, Lincoln's Inn Fields.' In the same year he won a gold medal from the Gentlemen and Noblemen's Catch Club (5). Although publication of his songs continued into the nineteenth century, the last book of his music appeared in 1769. He was elected a member of

the Society of Arts in 1769 and served on the Polite Arts, Mechanical Arts, and Chemistry committees. By 1771 he was organist at St Mary-at-Hill, Billingsgate, London, where he remained until his death.

He was a composer of instrumental and vocal music, including a collection of songs, especially those he wrote for entertainments performed at the Marybone, Ranelagh, Spring Gardens, and other pleasure gardens (entertainment complexes) in London. He published six books of Ranelagh songs; but nothing survives of his operas, his oratorio, *The Cure of Saul*, or of his ode, *The Invitation*. In 1763 he won a prize with one of his glees, *On Softest Beds*. A glee is an unaccompanied song for three or more solo voices in harmony (4). In 1759 he was the first to use the word sonatina in his *Twelve Sonatinas or Easy Lessons* (6). His galant works are considered cliché (5). Galant is a musical style featuring a return to classical simplicity after the complexity of the Baroque era. He was best known for his catches and part-songs, many of which were published in anthologies. Catch is a type of round in which the lines of music often interact so that a word or phrase is produced that does not appear if it is sung by only one voice (4). Part-songs written for multiple voices may be performed with or without instrumental or orchestral accompaniment. He also wrote an opera *Antigone* that was performed at Spring Gardens in London in February, 1764.

His more than 672 experiments in glassmaking were described in his "Experiment Book" (3,4). He was interested in learning chemistry, as it appears that he had no formal education in chemistry or glassmaking. Other objectives of the experiments were to prepare a clear glass melt, produce colored glass, some of which would

be imitations of natural gemstones, and make glasses for enameling metals. He was able to make colored glasses that could be ground and used to color enameled wares. He made gem-like glasses, either for the carved or molded "cameos and intaglios" that imitated antique stones or for the more prosaic false stones set into buckles, jewelry, picture frames, or other small metal wares. The Falcon, Salpetre Bank, and Whitefriars glasshouses allowed him to use their muffle or wind furnaces. These furnaces were found in the workshops of goldsmiths, watchmakers, and other artisans who might regularly use enameling colors. He probably used a smaller version, a kiln, for most of his experiments. For some of his products, he calculated the proportional gravity ratio of weight of glass in air to its weight in water for some of his products in 1766. In 1765, Delaval (7) suggested that proportional gravity or specific gravity was related to the color of glass. Perhaps Berg did not find this helpful as he did not use it after this year (3).

Berg died in 1775, between April 17 and May 4 (3).

Sir Edward William Elgar, Amateur Chemist-Composer
(1857-1934) (8-10)

Edward W. Elgar was born on June 2, 1857 in Broadheath, England. His father, who with his uncle owned a musical instrument shop, played the organ at the local Catholic Church. In addition to the organ, Edward played the bassoon, piano, and violin as well as being a conductor. When he was eleven, he wrote tunes for a play staged with his siblings, which were later published as *Wand of Youth Suites*. Ten years later, he composed *Harmony Music Four and Five Intermezzos*. In 1879 he became the conductor of the Worcester Amateur Instrumental Society and bandmaster to the Attendant's Orchestra at the Worcestershire County Lunatic Asylum in Powick. During the 1880s he played Popular Concerts in Birmingham, was a soloist at violin recitals for clubs, and taught violin to young middle-class ladies. In 1889 he married one of his pupils, Caroline Alice Roberts. One year later he composed a religious composition, *The Dream of Gerontius*, Opus



Sir Edward William Elgar

38, based on the poem of the same title by Cardinal Newman, a Catholic theologian. It relates the journey of a pious man's soul from his deathbed to his judgment before God and his settling into purgatory. In 1899 he completed the score for *Enigma Variations*. This was the work that finally secured his reputation as a composer of national and international standing. In this piece, fourteen people and one dog are featured. The first two *Pomp and Circumstance Marches* were composed in 1901 and the fifth and last in 1929. About the first march, he appreciated its worth and is quoted as saying: "I've got a tune that will knock 'em - knock 'em flat! ... a tune like that comes once in a lifetime ..." Elgar had 'arrived' (9).

His interest in science, prompted by new technology of the gramophone, led him to be the first major composer to record one of his own works in 1914. He conducted his composition, *Carissima*, in his first recording at the Gramophone Company on the "His Master's Voice" label, generally referred to as HMV. The company's London studios were located on an upper floor to minimize the effect of traffic noise and vibrations. The music was played with only a few instruments that could be clustered close enough to the recording horn. During World War I he wrote patriotic pieces such as *WWI*. He received many honors, including being created Knight Commander of the Victorian Order (K.C.V.O) in 1928.

After this event, he was known as Sir Edward Elgar.

One of his other interests was chemistry (11). At his Hereford house, Plas Gwyn, he set up a small laboratory in the basement. His manuscript of the *Prelude to The Kingdom*, dating from January 1906, bears the stains of his chemistry experiments. In August, 1908 he moved his laboratory to part of an outhouse. It was called The Ark because of the nesting of doves in the shed, and it had a telephone link to the house. A story about Elgar's hobby was related by W. H. Reed (12):

One day he made a phosphoric concoction which, when dry, would "go off" by spontaneous combustion.

The amusement was to smear it on a piece of blotting paper and then wait breathlessly for the catastrophe. One day he made too much paste; and, when his music called him, and he wanted to go back to the house, he

clapped the whole of it into a gallipot, covered it up, and dumped it into the water-butt, thinking it would be safe there.

Just as he was getting on famously, writing in horn and trumpet parts, and mapping out wood-wind, a sudden and unexpected crash, as of all the percussion in all the orchestras on earth, shook the room, followed by the "rushing mighty sound" he had already anticipated in The Kingdom. The water-butt had blown up; the hoops were rent; the staves flew in all directions; and the liberated water went down the drive in a solid wall.

Silence reigned for a few seconds. Then all the dogs in Herefordshire gave tongue; and all the doors and windows opened. After a moment's thought, Edward lit his pipe and strolled down to the gate, andante tranquillo, as if nothing had happened; and the ruined water-butt and the demolished flower-beds were pre-historic features of the landscape. A neighbour, peeping out of his gate, called out, "Did you hear that noise sir: it sounded like an explosion?" "Yes," said Sir Edward, "I heard it: where was it?" The neighbour shook his head; and the incident was closed.

When he moved to London in 1912, he turned to microscopes to satisfy his scientific curiosity.

Hydrogen sulfide (H_2S), known from alchemical times and variously named sulphur water or "Holy Water" (13), stinking sulphurous air (14), hepatic air (15), and—by Lavoisier—as "unknown combination" (16), became recognized as an important reagent for inorganic qualitative analysis (17). Elgar was one, although an amateur chemist, who produced a device to generate this important reagent, which he knew as sulphuretted hydrogen. As he wrote in a letter to August J. Jaeger, dated November 11, 1908 (10):

You will perhaps be amused - I hear that the 'new Sulphuretted Hydrogen Machine designed by Sir Edward Elgar' is to be manufactured & called the 'Elgar S.H. Apparatus'!! I will not offer to send you my invention - you would soon tire of it - although a nice toy.

This toy was "about as small as a hand (finger tip to wrist)." There is an inner chamber with a small hole at the top connecting it to the outer vessel. "The bottom of the outer vessel is perforated with a series of about 15 small drilled holes" (12, 18). It was made by the firm of Philip Harris (12, 18), and one is kept at Elgar's birthplace (19). His godsons, Atkins (20) and Kennedy (21) have written that it was patented. Atkins stated that it was "in regular use in Herefordshire, Worcestershire, and elsewhere for many years" (20).

Elgar died on February 23, 1934. He and his wife had one daughter.

Georges Urbain, Inorganic Chemist-Composer (1872-1938) (22,23)

Georges Urbain was born on April 12, 1872 in Paris, France. While he was studying at the École de Physique et Chimie de Paris, he was an assistant in the mineralogy chemistry laboratory where he met Pierre Curie, who inspired him to make chemical research his life work. In 1894, after he graduated as an Ingenieur-chimiste, he entered the Faculté des Sciences de Paris, where he started research in rare earths in the Laboratory of Organic Chemistry of Charles Friedel. Four years later he received the DSc. After six years in industry, he was appointed Assistant Professor of Analytical Chemistry at the Institut de Chimie, Sorbonne, Paris. In 1908 he was promoted to Professor of Mineral Chemistry. During World War I he was



Georges Urbain from (24)

Director of the Chemical Laboratory of the Technical Section of the Artillery, a member of Inspection des Etudes et Expériences Chimiques de Guerre, and President of the Comité Scientifique des Poudres et Explosifs and the Commission de Substances Explosives. In 1928 he became Professor of General Chemistry, Director, Institut de Chimie de Paris, and Codirector and Director of the Chemical Service, Institut de Biologie Physico-Chimique.

He was very popular with the students who "rose in a body when he entered the room" and "listened with such complete attention that there was not a murmur to be heard in the class of three hundred fifty students" (23). For his war service, he was made Chevalier la Legion d'Honneur in 1918 and Commandeur in 1933. In 1921 he was elected to the Académie des Sciences. He was an Honorary Member of the Chemical Society of London

and Corresponding Member of the National Academies of Belgium, Spain, and the USSR. He served as president of the French Chemical Society, Société de Chimie, and Société de Minéralogie.

Urbain was also a musician who played the piano and composed. Some of his compositions included, *A la veillée*, *Chanson d'Automne*, *Sur l'herbe*, and *Magagnose et Dyonisos*. In 1924, he wrote the book *Le Tombeau d'Aristoxène. Essai sur la musique*, in which he applied the scientific method to the study of music (25). In addition, he was a painter and sculptor.

In 1879 Lars F. Nilson separated Marignac's ytterbia into scandia and a new ytterbia, which Urbain then separated into neoytterbia and lutecia (ytterbium and an unknown element) in 1907. In the same year, K. Auer von Welsbach reported the spectra and atomic weights of two elements in ytterbia, which he named after the stars aldebaranum and cassiopium. Urbain named the element lutecium (Roman name for Paris), which was later changed to lutetium. Between 1895 and 1912 he worked on the rare earths and performed more than 200,000 fractionations to afford the elements samarium, europium, gadolinium, terbium, dysprosium, and holmium. In 1911 Urbain had studied element number 72, which he called celtium. The discoverers, D. Coster and G. von Hevesy, however, named it hafnium in 1923. He also discovered the law of optimum phosphorescence of binary systems and carried out research in isomorphism. He converted an analytical balance into a thermobalance before Kotaro Honda and discovered the law governing efflorescence of hydrates in a dry atmosphere. He also served on the International Commission on Atomic Weights.

Urbain wrote several books dealing with various chemical topics, spectrochemistry, 1911 (26), chemistry of complexes with A. Sénéhal, 1913 (27), chemical reactions, 1925 (28), and a general chemistry text with P. Job, G. Allard, and G. Champetier, 1939 (29).

Urbain died on November 5, 1938.

Emil Votoček, Organic Chemist-Composer (1872-1950)
(8, 31-32)

Emil Votoček was born in Arnau (Hostinné nad Labem), Bohemia, on October 5, 1872. After graduating from the gymnasium, he attended the School of Commerce in Prague where he developed an interest in chemistry. So, he transferred to the School of Chemistry (now the Prague Institute of Chemical Technology) of the Czech Technical University. In 1893 he received a diploma with the

degree of Ingenieur (33). Then he continued his studies in Germany, first at Mulhouse in Alsace-Lorraine, and a year later at Georg-August University in Göttingen. He returned to the Czech Technical University as an Assistant in 1895 and was promoted to Docent in 1905. One year later he was appointed Extraordinary or Associate Professor of Organic Chemistry and was promoted to Ordinary (Full) Professor of Inorganic and Organic Chemistry in 1907. He served as Rector of the University during 1921-1922, and in February, 1939 he was forced



Emil Votoček as Rector of the Czech Technical University from (32)

to retire by a decree from the Department of Education. However, he enrolled as a student so that he could continue his research. After the conquest of Czechoslovakia by the Germans, the universities were closed by order of the German occupation officials on November 17, 1939, until the country was liberated in 1945.

Although he was regarded as a learned and respected professor, he was often hot-tempered and irritable. His research laboratory was known as "Devil's Island," which represents the appearance and the mood in the laboratory (32). He lectured in both inorganic and organic chemistry and wrote textbooks in both fields. K. Preis and he wrote the inorganic text with Jaroslav Heyrovský (34). In the organic text (35) he introduced a new classification of organic chemicals dependent upon whether a compound was derived from the original hydrocarbon by substitution on one, two, or more carbon atoms. He also wrote a laboratory manual and a book of exercises in organic chemistry (36).

Votoček received honorary doctorates from the Czech Technical Universities of Prague, 1948 and Brno, 1927, the Universities of Padua, Nancy, and Toulouse, 1929, and from the Sorbonne. He was an honorary member of the Polish, Italian, Spanish, and Romanian

chemical societies, the Société de Chimie Industrielle, and the Société Chimique de France, which awarded him the Le Blanc Medal; and he was named Officier de la Légion d'Honneur and Officier de l'Instruction Publique. Other honors included the Ordine Corona d'Italia and Commander of Poland's Order of Polonia Restituta, 1932. He was nominated for the Nobel Prize in Chemistry in 1933, a year in which it was not awarded (32). However, one of his students, Vladimir Prelog, received the Nobel Prize in 1975 for his research into the stereochemistry of organic molecules and reactions, which he shared with John Cornforth for his work on the stereochemistry of enzyme-catalyzed reactions. On the centenary of his birth, 1972, a commemorative medal was minted and is awarded by the Rector of the Prague Institute of Chemical Technology as the highest recognition of scientific activity,

He played the double bass in addition to being a musicologist and composer. Among the 70 songs and works for piano and ensembles he wrote are *Allegretto grazioso*, 1932, *Thema con variazioni for piano and Soprano Voices*, 1934, *Trio for Piano, Violin, and Violoncello*, 1938, *Serenade for French Horn and String Quartet*, 1943, *Czech Polka*, 1944, *From Dawn to Dusk of Life*, 1945, and *The May Fairy Tale*, 1949. In 1946 he published the book, *Musical Dictionary of Foreign Expressions and Phrases* (37).

Among his many literary achievements were several chemical dictionaries for different languages: *Shorter German-Czech and French-Czech Chemical-Technical Dictionary* with B. Setlík, 1906 (38); *Czech-German-French-English-Italian-Latin Chemical Dictionary*, 1941 (39). He also published several for other sciences: *Czech-French-Terminological and Phraseological Dictionary for Chemistry, Physics and Related Sciences*, 1924 (40); *Polish-Czech Chemical Dictionary with Partial Regard to Mathematics, Physics, Geometry and Mineralogy*, 1931 (41). Two dictionaries dealt with the Czech and French languages: *Czech-French Conversation and Phraseology*, 1939 (42) and 1924 (40). He published two volumes containing all postmarks used in Bohemia up to 1918 (43). In 1929 he started the journal *Collection of Czechoslovak Chemical Communications* with Jaroslav Heyrovský, who received the Nobel Prize in Chemistry in 1959 for work in polarography. They also served as the editors until the journal ceased publication in 1939. When the journal resumed publication after World War II in 1947, Heyrovský continued as sole editor (44).

Votoček's research on artificial dyestuffs, carbohydrates, and analysis of natural products was published

in 300 articles. One of his main research interests was saccharides, especially methylpentoses. This interest was developed during his stay in Göttingen, where he worked with Bernard C. G. Tollens, who was noted for his research of the chemistry of saccharides. He studied the derivatives of rhamnose, L- fucose and its D-isomer, which he named rhodose. To describe two sugars that can be converted into each other, he invented the term epimers and the term epimerization for the reaction. He introduced the use of nitrous acid in the oxidation of sugars and synthesized a number of saccharides and saccharide acids and alcohols. Some of his efforts were devoted to nomenclature in carbohydrates and (with Alexander Sommer-Batěk) in inorganic compounds. He also served on the IUPAC Commission on the Nomenclature of Organic Chemistry. One of his studies on the derivatives of carbazole led to its application as an analytical reagent (Votoček's reagent) for the determination of sulfite in the presence of thiosulfate and thionate. He also introduced the use of sodium nitroprusside as an indicator in mercurimetric titrations. A more comprehensive account of his chemical work can be found in Ref. 32.

On February 17, 1906, he married Libuše, the daughter of an Austro-Hungarian minister; they had two sons and a daughter. He died October 11, 1950 in Prague.

Contemporary Chemist-Composers

The tradition of chemist-composers continues to the twenty-first century as illustrated by the activities of three contemporary chemist-composers, E. L. Bearer, Morris Kates, and Carlo Botteghi.

E. L. Bearer, Biochemist-Composer (8, 45)

Elaine L. Bearer was born on April 1, 1949 in New Jersey. Her early education began at age 6, and by age 9, the first performance of one of her compositions took place. After studies at Juilliard Prep School, she matriculated at Carnegie Institute of Technology, where she studied both music and computer science. Composition studies were with Carolos Surinach, Virgil Thompson, Don Wilkins, and Nicolai Lopatniff. She left Carnegie Tech after two years to travel to Paris, where she worked with Nadia Boulanger, the famed composition teacher. Returning to New York, with an interest in computer "algorithms" to generate sound, she completed a B. Music in 1970 from the Manhattan School of Music. From 1970 to 1973 she was an instructor in music history and appreciation at Fairleigh Dickinson University. Then she was recruited to San Francisco by Lone Mountain College as an Assis-



Elaine L. Bearer

tant Professor of Music in 1973, after having withdrawn from the Ph.D. program at NYU, which awarded her an M. A. in Musicology in the same year. After teaching composition at Lone Mountain, SF State University, and the San Francisco Conservatory, she decided to attend medical school. While preparing at Stanford University, she was a postgraduate research assistant in neuroscience with John Nicholls and a teaching assistant for Donald Kennedy. She was the first graduate from the M.D.-Ph.D. program at University of California, San Francisco in 1983. Then she served a residency in pathology there for two years. After a year at the Centre Médical Universitaire, University of Geneva, Switzerland, she returned for a postdoctoral fellowship in biochemistry with Bruce M. Alberts. In 1991 she joined the Department of Pathology and Medicine of Brown University as Assistant Professor. One year later she was appointed Adjunct Assistant Professor in the Department of Music. After six years, she was promoted to Associate Professor in both departments and Professor in 2004 in the Department of Pathology and Medicine and in 2005 in the Department of Music and in 2006 in the Division of Engineering. Since 1993 she has served as Director and Codirector of The San Lucas Health Project, which provides the indigenous Maya of the San Lucas Toliman, Guatemala region with free year-round primary health care.

One musical composition, *The Nicholls Trio: A Musical Biography of a Scientist*, is dedicated to her mentor, John Nicholls (45, 46). The final movement was inspired by electrical patterns in the neurons of leeches, which Nicholls studied. The piece was premiered at the annual meeting of the Society for Neuroscience in 1994. Her *Magdalene Passion* (45, 46), an hour-long oratorio for chorus, orchestra, and five soloists, was premiered in 2000 by the Providence Singers under Julian Wachner

In her research in molecular biology of actin-cytoskeleton, Bearer investigates dynamic cellular behavior. Presently, she uses a range of microscopic imaging and molecular techniques to understand the mechanisms of

these dynamics by using model systems, including squid giant axon, transport of Herpes simplex virus, and human blood platelets. Some of her recent studies address fundamental questions pertaining to learning and memory. She has published 45 papers on her research and is the editor of *Cytoskeleton in Development* (47) and co-editor of *Nature and Nurture* (48).

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Carlo Botteghi, Industrial Chemist-Composer (1938-2002) (49,50)

Carlo Botteghi was born in La Spezia, Italy, on March 5, 1938. In 1963 he graduated in chemistry from the University of Pisa. He continued there as a Lecturer of Organic Chemistry in the Faculty of Engineering until 1968. Then he took a research position at ETH (Polytechnic Institute) in Zürich, Switzerland, as Forschungsassistent and Oberassistent. He was also Lecturer in Organic Chemistry in the Faculty of Engineering and Director of the high pressure laboratory. In 1975 he became Professor of Industrial Chemistry at the University of Sassari, Italy, and Director of the Institute of Applied Chemistry. After ten years he became Professor of Industrial Chemistry at the Università Ca' Foscari di Venezia (University of Venice), Italy. In addition to teaching various courses in the area of industrial chemistry, he served as Director of Department of Chemistry for two 3-year terms.



Carlo Botteghi from (50)

He studied piano and music composition privately and has been registered in the Music Section of the Italian National Register of Authors since 1960. As a musicologist, he concentrated mainly on Pietro Mascagni (1863-1945), who was one of the important Italian composers at the turn of the 20th century, best known for his first masterpiece *Cavalleria Rusticana*. He was a noted Mascagni scholar or Mascagnano and the head of the Centro Studi Mascagnani of Livorno. In 1995 he wrote the music for the song *Mascagni* with words by Luigi Biagioni. It may be found on a CD entitled *Cieli*

di Toscana (Tuscan Heavens) performed by the popular Italian singer, Andrea Bocelli. In 1981 Carlo Botteghi wrote *Magari tu and Una giornata senza te* with words by Antonio Strinna. His book, *Le Suggestioni della Musica* (The Splendor of Music) was published in 1992 (51). In 1997 he published an essay on the opera, *Parsina*, entitled *Parisina – il dramma musicale di Gabriele D’Annunzio e Pietro Mascagni* (Parisina-the musical drama by Gabriele D’Annunzio and Pietro Mascagni) (52).

Botteghi published 150 papers in organic chemistry, homogeneous catalysis, hydroformylation, and carbonylation. One of his interests was conservation of buildings, and he did research in the synthesis of polymeric materials for this use. From 1995 to 1998 he also taught Conservation of Materials in Historical Buildings at the Architecture University Institute in Venice.

Botteghi died suddenly on September 19, 2002 and was survived by his first wife, Maria Grazia Bacci, and their two sons and his second wife, Vera Bellagamba, and their son.

Morris Kates, Biochemist-Composer (53,54)

Born in Galati, Romania, on September 30, 1923, Morris Kates was brought to Ottawa, Canada, one year later. He received a B.A., 1945, M.A., 1946, and a Ph.D., 1948 from the University of Toronto. After receiving his doctorate, he continued at the University as a postdoctoral fellow and then moved to the National Research Council of Canada, where he was first a Postdoctoral Fellow (1950-1951), and then a research scientist until 1968. In that year, he transferred to the Department of Biochemistry, University of Ottawa, as Professor, where he remained until he retired in 1989 as Professor Emeritus. During his tenure at the University of Ottawa, he served as Chairman of the Department of Biochemistry (1982-1985) and Vice-Dean (Research), Faculty of Science and Engineering. In 1995 he was named the Morton Lecturer, an award by the Biochemical Society to a lecturer who has made an outstanding contribution to lipid biochemistry. He also received the Supelco Award for lipid research from the American Oil Chemist Society in 1981. An issue of *Biochemistry and Cellular Biology* in 1990 was dedicated to him in honor of his valuable contributions to biochemistry in Canada (55).

Kates developed his twin passions for science and music during his youth and began studying violin at the age of 11. By the time he was in high school, he began composing music and exploring the world of laboratory

science. During his university studies he took courses in music harmony, counterpoint, and composition and played in the University of Toronto Orchestra. When he was at the National Research Council, he played in orchestras and



Morris Kates from (53)

string quartets in Ottawa. His first formal composition in 1946 was *Theme and Variations for Piano*, which was revised for strings in 1964. In 1990 he composed *Columbus* for baritone and full orchestra, and two years later, *Festive Suite for Brass Quintet and Strings*. His composition for choir and string quartet *Water—Source of Life* was released in 2000. He is an Associate Composer with the Canadian Music Centre and a member of the Canadian League of Composers.

Kates has published about 220 articles on the analysis, structure determination, biosynthesis, and membrane function of cellular phospholipids, the nutritional value of lipids, and the production of biodiesel fuel. One of his research projects was the discovery and study of a new class of glycerol-diether lipids in bacteria named *Archaea* that live in extreme environments. He is currently associated with the Ottawa Biodiesel Research Group in the Department of Chemical Engineering at the University of Ottawa, whose “main objective is to produce biodiesel in a cost-effective way by overcoming several barriers to biodiesel profitability”(56).

His books include *Techniques of Lipidology: Isolation, Analysis, and Identification of Lipids*, which is now in the second edition (57). In 1980 he and Arnisa Kulis edited *Membrane Fluidity: Biophysical Techniques and Cellular Regulation* (58), and four years later, with Lionel A. Manson, he edited *Membrane Fluidity – Biomembranes*, Vol. 12 (59). In 1990 he edited *Glycolipids, Phosphoglycolipids, and Sulfoglycolipids*, which is volume 6 of the *Handbook of Lipid Research* (60). Three years later he coedited *The Biochemistry of Archaea (Archaeobacteria)*, *New Comprehensive Biochemistry*, Vol. 26, with D.J. Kushner and A.T. Matheson (61).

Kates is married to Pirkko Helena Makinen, and they have three children and seven grandchildren.

Observations

The chemist-composers described above are experimental chemists; two amateur chemist, two biochemists, an industrial chemist, an inorganic chemist, two organic chemists, and a polymer chemist, but none is a physical or theoretical chemists. In performing experimental work, one sometimes involves “hunches” in solving problems, which may be more similar to the brain processes used in composing music than the abstract reasoning needed in solving problems in physical or theoretical chemistry. This does not apply to chemist-performers because some are physical chemists (e.g., Wilhelm Ostwald). Nor does it apply to several of the scientist-composers who are also mathematicians and physicists (62). It may be that the sample of nine chemist-composers is too small to derive any correlation between the area of chemistry pursued by the chemist-composers and their music.

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ABOUT THE AUTHOR

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LETTER TO EDITOR

In his recent review, Dennis Rouvray concedes that my book on the periodic table is among the “three exceptional books” that have ever provided an in-depth treatment of this chemical icon (1). However, Rouvray quickly complains that my book stays too close to the previous comprehensive book on the subject “supporting van Spronsen’s assertion that Mendeleev was by far the most important discoverer in terms of his lasting impact.” As I assume most readers would agree this is a rather astonishing statement, since if there is *any* unanimous agreement about the periodic table it is precisely that Mendeleev has indeed had the most lasting impact! Who after all is supposed to have eclipsed Mendeleev?

Rouvray fails to mention an entire chapter that I devote to Mendeleev’s predictions where, contrary to van Spronsen and many others, I claim that the acceptance of the periodic system was not primarily the result of Mendeleev’s predictions but due, in equal measure, to his accommodation of the properties of the elements.

The reviewer reveals a naively scientific attitude in protesting that I fail to adopt a stronger position over the question of whether chemistry has been reduced to quantum mechanics or on what the optimal representation of the periodic system might be. Rouvray does not seem to appreciate the virtue of exploring open-ended philosophical questions and not necessarily arriving at clear-cut conclusions, which one feels compelled to strenuously defend in the way that Henry Bent does for the left-step periodic table, for example. And on the question of my support for the left-step table, I must say that I am rather glad that I expressed certain reservations since I have subsequently changed my preference in favor of a completely different representation that I have recently proposed (2).

Finally, I cannot refrain from making two more general points. The first is that my book has been almost universally praised by about twenty reviewers including chemists, chemical educators, historians, and

philosophers of whom I cite just a few (3-6). Secondly, I find it difficult to believe that Rouvray’s review of my book, his second incidentally, is completely unrelated to the appearance, in *Foundations of Chemistry*, of a substantially less than stellar review of a collection of papers on the periodic table that he has edited (7). *Eric Scerri, University of California, Los Angeles.*

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Dennis Rouvray replies:

Evidently my review of Scerri's book was a bit too close to the truth for comfort. It seems to have him so flustered that he felt impelled to launch out on a rant that he topped off with an *ad hominem* attack. Scerri needs to get his impetuous emotions under control and realize that ranting and raving and especially personal attacks are never a good idea. They alert the reader to the fact that arguments have been put forward that cannot be answered other than by vulgar abuse. Although Scerri's protestations could easily be rebutted point by point, I choose to refrain from a duel with an individual who is so obviously unarmed.

BOOK REVIEWS

The Pauling Catalogue, Oregon State University Libraries, Corvallis, OR, 2007, 6 vol., \$ 125.

As Francis Bacon wrote some four hundred years ago “Some books are to be tasted, others to be swallowed, and some few to be chewed and digested.” — Francis Bacon, English philosopher, essayist, statesman, and jurist, *Essays*.

This set of books certainly fits into the first category: to be tasted, not by a single nibble but by many, at different places, at random or systematically; both approaches will be rewarding. The collection is a complete catalogue of everything Pauling kept. Some people never throw anything away. In particular, they keep every scrap of paper. Pauling was one of these. From an early age he kept anything written that concerned him: manuscripts of publications, lecture notes, laboratory notebooks, research notes, letters received, copies of letters sent, newspaper clippings, photographs, all the other paraphernalia that turned up in the course of a long, active, creative life. Presumably he knew already as a young student that he was going to be important and that everything that concerned him would later, after his death, be of interest to historians and students of science. There is correspondence with hundreds of chemists, physicists, and biologists all over the world who left their mark on twentieth-century science, as well as with politicians and other public figures during World War II and the long cold war that followed. For the illustrations alone, nearly twelve hundred of them, anyone interested in Pauling's life should buy the catalogue. In Volume V there is a photograph of the five-year old Linus, already a person to be reckoned with—and it is clear that he was

already aware of this (Photograph supplied by Oregon State University Libraries).

Apart from the illustrations and some introductory material by several authors, including an extensive year-by-year account by Robert Paradowski of the main events in Pauling's life from childhood onward—even earlier since his ancestry is also traced—the six volumes consist of lists: lists of the vast store of documents, more than a half million of them, held in the collection of *Ava Helen and Linus Pauling Papers* at Oregon State University Library. These lists make it possible for anyone to trace whether any particular document or set of documents exists in the collection and to identify it by a simple code. The individual volumes deal with the many facets of Pauling's life and his relationships with the world.

Volume 1 lists his correspondence, including post-cards, with the outside world: scientists, politicians, public figures, everyone excepting family. This is followed by a complete list of his publications, not only scientific papers and books, but also popular articles, letters to the editor, and so on; then follows a list of manuscripts and typescripts of articles and of his many speeches delivered at various occasions through the years. It is interesting to see how the emphasis gradually changed from purely scientific topics towards political themes and health, although scientific topics still held his attention to the very end. Volume 1 continues with lists of manuscripts and typescripts of articles and speeches, together with relevant correspondence.

Volume II, the Science Section, lists material connected with Pauling's scientific work, divided into fifteen subsections, ranging from structural chemistry and quantum mechanics through the beginnings of what was

to become molecular biology, and including his work on numerous scientific advisory committees. Also included here are guidelines to the contents of Pauling's forty-six research notebooks, spanning the years from 1922 to 1994, fascinating material providing glimpses of how he approached scientific problems. An appendix to this volume contains extracts from Pauling's 1917 diary, begun during the time when he was preparing to enter Oregon Agricultural College without a high school diploma. He sometimes felt unequal to the task. He wrote: "I will not be able ... to do justice to the courses ... but it is too late to change now... so I will only do my best."

Volume III contains the Peace Section, consisting of material related to Pauling's work on behalf of world peace, including the famous 1957 petition to the United Nations, signed by more than 11,000 scientists, to stop the testing of atomic weapons. To modern sensibilities, it seems incredible that there could have been popular as well as official opposition to such a petition at a time when tons of radioactive material were being liberated every year into the atmosphere. But opposition there was: witness his encounter with the U. S. Senate Internal Security Sub-Committee (Volume IV). Eventually, Pauling's initiative led to the 1963 Partial Test Ban Treaty and to the award of the Nobel Peace Prize in the same year. In his long life, Pauling received many other honors and awards, far too many to mention here; they are all listed in Volume III, which also contains a section devoted to material relating to Linus's wife Ava Helen, a supporter and fellow activist from 1923 until her death in 1981, and manuscripts of articles and speeches, as well as correspondence with family and friends.

Volume IV contains material concerning various aspects of Pauling's life and career: academia, political issues, legal, business and financial, personal and family, and scrapbooks. In addition, it lists the contents of Pauling's personal safe, including intimate letters between Linus and Ava Helen, as well as other documents of a sensitive nature, such as correspondence relating to the Bomb Test Petition and other controversial matters. The personal safe also contains information about Pauling's scientific war work dealing with blood plasma substitutes and rocket propellants, much of it still marked "secret" on arrival at the Library and requiring belated official clearance.

Volume V lists extensive audiovisual material extending over several decades, from audio-cassette tapes to film reels, documenting public lectures, and radio and television interviews. It also contains information about more than 5,000 photographs of Pauling, his fam-

ily, and friends. Finally, comes Volume VI. This lists newspaper clippings, magazine profiles, and journal articles concerning Pauling, and—surely one of the most interesting collections, at least for me—the catalogue of his personal library of more than 4,000 books, revealing the range of his reading. A library tells one a lot about its owner. Scanning through this list, one may feel rather like a visitor in the library of a famous personage, snooping through the shelves to infer something about the literary tastes and interests of one's host. One finds here, as expected, works on science, health, history, and politics; not much on music, art, and literature, neither classical nor modern; no Joyce, no Kafka, no Proust, but, perhaps surprisingly, T. S. Eliot, *Collected Poems 1909 - 1935*. Pauling evidently had a taste for detective stories—more than twenty volumes by Georges Simenon—and for crossword puzzle collections.

One can go on, picking raisins from a rich cake—six rich cakes containing many thousand raisins and plums. It must be made clear; the *Catalogue* is not a biography, far from it. For that the best offering is probably still Thomas Hager's 1995 *Force of Nature: The Life of Linus Pauling*, but it provides an immense amount of information about Linus Pauling and his times and will be the invaluable source of material for future biographies, especially those that will be written when we, the people who knew Pauling, listened to him, argued with him, and learned from him, have passed on. Jack D. Dunitz, ETH-Zürich, Switzerland.



Photograph: The five-year old Linus Pauling (with permission of the Oregon State University Library, Special Collections).

Lavoisier in Perspective. Marco Beretta, Ed., Deutsches Museum, Munich, 2005, hardcover, 207 pp, ISBN 3-924183-07-4, € 24.80.

In 2003, the Deutsches Museum in Munich decided to celebrate its centennial by inducting the great French chemist, Antoine-Laurent Lavoisier, into its Ehrensaal, or Hall of Fame. A bust of Lavoisier was commissioned and placed in the hall among those of other great scientists, all of whom were (at that time) German. To further underscore the museum's earnest departure from nationalistic exclusivism, a group of international scholars (four German, four Italian, two French, and one each American, Japanese, and Canadian) were assembled under the able direction of Marco Beretta (University of Bologna) for a two-day symposium of which this collection of essays is a consequence.

As in almost any such collection, the styles, methodologies, subjects, and approaches of so many diverse authors make a summary evaluation difficult. Simplifying the task somewhat is the fact that presentations from each of the three sessions of the symposium were devoted to a common theme. The first session, for example, dealt with—to use the editor's words—“Lavoisier's experimentalism through his use of innovative instruments, such as the calorimeter and gasometer, and the theories which stood behind them.” Three of the articles in this section follow precisely the conference theme, “Lavoisier in perspective,” by not only analyzing Lavoisier's experiments on calorimetry, gasometry, and respiration physiology (spiroergometry) but by placing them in a larger historical framework that identifies Lavoisier as the founder of several significant lines of scientific research, some of them having to do not merely with chemistry but also with physics and physiology. In addition, Peter Heering of the Carl-von-Ossietzky University, Oldenburg, presented an interesting summary of a work in progress, the attempted replication (in so far as it is possible) of the calorimeter of Lavoisier and Laplace. The object of this exercise is to ascertain through historical reenactment of the original experiments details of specific conditions and procedures that the eighteenth-century experimenters failed to mention or were, perhaps, even unaware of. Results so far are only preliminary.

If there is one thing that nearly every historian of chemistry agrees upon, it is the oft-repeated view that the essential contribution of Lavoisier's chemistry was based upon a careful comparison of the weights of all

the substances entering into chemical reactions to the weights of all the substances emerging from them—in C. C. Gillispie's words, “the spirit of accountancy raised to genius.” In his symposium contribution, Jean-Pierre Poirier, an economist and recent biographer of Lavoisier, demonstrates convincingly that this “balance sheet method” pervaded nearly all aspects of Lavoisier's career, not only in chemistry (from almost before its very beginnings), but in his directorship of the Gunpowder Commission, his tax farming, his experimental agricultural work at Freschines, his presidency of the Board of Directors of the Discount Bank, etc. Poirier also attempts to trace (somewhat less convincingly, I think) the origin of Lavoisier's quantitative methodology to his precision-obsessed teacher of mathematics and astronomy at the College Mazarin, the Abbé Nicolas-Louis de la Caille.

As the divisions between the articles of this book are not manifest, Poirier's presentation could just as easily belong to the second session, devoted to “the strategies Lavoisier adopted in order to persuade his public of the validity of the new approach to chemistry.” This section of the book is the least successful in coherently satisfying its avowed purpose. The papers range from a fascinating and well contextualized assessment (by Keiko Kawashima at the Nagoya Institute of Technology) of Madame Lavoisier's motivations in assisting her husband as translator of scientific works from the English, artist, and recorder in the laboratory to what amounts to a detailed catalogue (by Patrice Bret, General Secretary of the Lavoisier Committee) of Lavoisier's institutional affiliations (accompanied by charts). The first article, although excellent in itself, has only a remote association with Lavoisier's persuasive strategies, and the second, although clearly related to the dissemination of Lavoisier's influence, is more a like a reference work than a coherent historical essay.

In his article Ferdinando Abbri (University of Siena at Arezzo) attempts to widen the perspective of the Chemical Revolution by showing that it consisted of much more than a simple Anglo-French dialogue concerning pneumatics and that Lavoisier's complex relations to researchers of other nationalities, primarily German and Scandinavian, cannot be ignored. Abbri points especially to Lavoisier's connections to Georg Ernst Stahl (creator of the phlogiston theory), Johann Friedrich Meyer (whose theory of *acidum pingue* Lavoisier once found attractive), and finally to the great Swedish chemist, Carl Wilhelm Scheele, whose rival theories on fire and air Lavoisier confronted with a detailed and extensive critical analysis.

The final section of the book, devoted to the “image of Lavoisier in modern historiography, with particular attention to the Franco-German debate,” consists of two papers which, taken together, provide an interesting comparison of the diverse uses (and abuses) that (primarily nineteenth century) German and French chemist/historians made of Lavoisier’s image. According to Christoph Meinel (University of Regensburg), the German chemists endeavored to use Lavoisier to “define the boundaries of their discipline,” and their assessments of his career were influenced by (among other things) nationalistic prejudices, the increasing preeminence of organic chemistry (where Lavoisier’s new nomenclature was largely irrelevant), and the widespread notion that Lavoisier’s major scientific contributions lay more in the realm of physics than in the realm of chemistry (in an era in which chemists were increasingly and understandably concerned about disciplinary autonomy). Mi Gyung Kim (North Carolina State University) presented what may be considered a companion to the preceding article. Although dealing with French historiography of the Chemical Revolution in general, she concentrates her attention primarily on the ways in which three of the most prominent nineteenth-century French chemists, Jean-Baptiste Dumas, Charles-Adolphe Wurtz, and Marcellin

Berthelot, manipulated interpretations of Lavoisier’s achievement to reflect favorably on their own careers.

Following this collection of scholarly articles, Marco Beretta and Andrea Scotti append a kind of tour of their extraordinary web site, the Panopticon.Lavoisier (<http://moro.imss.fi.it/lavoisier/>), at which they have assembled in one virtual location an enormous trove of primary and secondary sources concerning Lavoisier and the Chemical Revolution, including six volumes of Lavoisier’s collected works, bibliographies of primary and secondary sources, digitized articles, chronologies, iconographies, and much more. Scholars will now be able to do much of their research without having to desert the comfort of their armchairs and without having to worry about bus schedules or library closing times.

Despite some excellent and interesting essays, what we have in this book is, on the whole, a more-or-less typical collection of conference papers; and like most such papers, there is little in them that one could call earth-shakingly novel. With few exceptions, they tend to be fairly narrowly conceived, highly specialized, and of interest primarily to professionals in the field. *Prof. Jerry B. Gough, Department of History, Washington State University, Pullman, WA 99164.*

J. C. Poggendorff—Leben und Werk. Heiner Kaden and Benno Parthier, Ed., Wissenschaftliche Verlagsgesellschaft mbH, Stuttgart, 2005, 61 pp, ISBN 3-7776-1406-8, € 33.

Mathematikern, Astronomen, Physikern, Chemikern, Mineralogen, Geologen usw. aller Völker und Zeiten, Gesammelt von J. C. Poggendorff, Mitglied der Akademie der Wissenschaften zu Berlin.

End of an Era

“Poggendorff,” a byword for historians of science, is one that rolls easily and unconsciously off the tongue as do “*Beilstein*” for organic chemists and “*Gmelin*” for inorganic chemists. The complete title for the multi-volume biographical-bibliographical work, coined by its founder J. C. Poggendorff, although fully descriptive of the contents, is virtually unknown:

Biographisch-literarisches Handwörterbuch zur Geschichte der exacten Wissenschaften enthaltend Nachweisungen über Lebensverhältnisse und Leistungen von

The occasion for the appearance of this current German publication, edited by Heiner Kaden, Sächsische Akademie der Wissenschaften zu Leipzig, and Benno Parthier, Deutsche Akademie der Naturforscher Leopoldina, Halle, is the remarkable milestone for this invaluable resource: publication of the last volumes and thus the discontinuation of the work, after 141 years. The book consists of publication of a series of lectures presented in Leipzig in October, 2004 “..aus Anlass des Abschlusses eines

Jahrhundertwerkes” [on the occasion of the termination of a centuries-old work.]

After an explanatory introduction by the co-editors, there follow five presentations describing J. C. Poggendorff as scientist, editor, and biographer. The first, by the final editor of *Poggendorff*, Hans Wussing, covers the founding and continual growth and development of the reference work up to the final days. In the second lecture Martin Henke pays tribute to a generous benefactor, Berend Wilhelm Feddersen, whose financial support enhanced the publication of *Poggendorff* and guaranteed its continuation. Next, Gotthard Lerchner provides perspective for the publication of *Poggendorff* along with other contemporary German bibliographies and brings the audience up to the present time with the development of electronic data bases. Poggendorff the man is described both personally and professionally in the next two lectures by Heinz Penzlin and Heiner Kaden.

Although the attractive publication, part of an extensive series of treatises emanating from the Saxon Academy of Sciences in Leipzig, is only 61 pages in length, it provides a generous offering of fascinating information about J. C. Poggendorff the scientist and the conception and lasting legacy of *Poggendorff*. Only some of the highlights can be covered in this review. Readers would be rewarded by delving into more of the rich historical details.

Poggendorff the Scientist and Editor

Johann Christian Poggendorff (1796-1877), one of 14 children born in Hamburg, was educated privately and then became a pharmacist's assistant, where he continued to study independently by taking advantage of his supervisor's library. Moving to Berlin in 1820, he enrolled in the 10-year-old Friedrich-Wilhelms University, later to be renamed the Alexander von Humboldt University. Encouraged by his friend Friedlieb Ferdinand Runge (1795-1867), Poggendorff and Runge set up a laboratory in their shared living quarters, where they carried out scientific experiments. While attending lectures at the university, Poggendorff completed a self-directed study on “Physisch-chemische Untersuchungen zur näheren Kenntnis des Magnetismus der voltaischen Säule,” which was published in *Isis von Oken* in 1821. This work—Physical-chemical Investigation of a Better Understanding of Magnetism in the Voltaic Pile—is often cited as the forerunner of measuring devices for minute electric currents.

Poggendorff was never examined for a degree at the university. He remained independent but professionally recognized, having been elected to the Königl. Akademie der Wissenschaften, Berlin in 1823. Particularly noteworthy is the awarding of the honorary “Doktordiplom” by F-W University in 1834, a tribute to his meritorious achievements in physics. First appointed as a professor without salary, Poggendorff was given an annual remuneration of 200 taler after 1842. He lectured at the university until the age of 78, primarily in the history of physics and chemistry. In exchange for an apartment, Poggendorff performed meteorological measurements in the academy's observatory, where Mitscherlich and Heinrich Rose also had laboratories. He became a life-long friend of the brothers Heinrich and Gustav Rose. He married the cousin of the wife of Heinrich Rose, and his daughter later married the son of Gustav Rose. In his lecture Penzlin includes a family tree covering five generations.

With the urging of Heinrich Rose, Poggendorff became the second editor of *Annalen der Physik und Chemie* in 1824 (the first being L. W. Gilbert) and moved the operation, which he continued until his death 52 years later, from Leipzig to Berlin. The highly respected periodical soon became known as the *Poggendorffsche Annalen*. His first volume contained publications by Berzelius and H. and G. Rose. Heinrich Rose published exclusively in Poggendorff's journal thereafter. Declining professorial offers at Gießen and Leipzig, he opted to be independent as editor, science historian, and member of the Berlin faculty and the Berlin Academy.

Poggendorff, The “Handbook”

Poggendorff's early fascination with history of science and scientists may have originated from a work he co-edited with Liebig, *Wörterbuch der Chemie*, published in 1836 by Vieweg, Braunschweig. Many notable chemists and physicists of the day—Gay Lussac, Magnus, Wöhler, Graham—contributed to the effort. By 1856 Poggendorff was working seriously on a collection of biographies of scientists (defined broadly, as is reflected in the full title of the handbook). The first two volumes (I and II), covering scientists in alphabetical order, was published by Verlag J. A. Barth in 1863. It contained 8,500 entries of scientists: birth, death, academic training, and a comprehensive list of publications, arranged by periodical source. Poggendorff had accumulated extensive material for supplemental volumes by the time of his death in 1877. The legacy was continued by a host of dedicated

editors and benefactors, with the result that additional volumes continued to appear, albeit irregularly [III, 1898; IV, 1904, V, 1925; VI, 1940 (4 parts)]. Material that had been gathered for subsequent volumes, beginning with 1932, was destroyed during WWII; but nevertheless Volume VIIa (in 5 parts), limited to German speaking scientists, appeared in 1951. This was followed by a bibliography of international scientists in Volume VIIb (8 parts) in 1971. Now with the completion of Volume VIII in somewhat abbreviated form (but still "A-Z"), the editorial board and publisher came to the painful conclusion that the project must come to an end. Historians

of science need not despair, however, for Poggendorff survives in electronic form, with 28,000 entries! [See www.poggendorff.com]

In one final paper in this symposium, B. Parthier provides tables of 19th-century members of Leopoldina-Akademie, Halle: one of physicists, 1791-1895, one of chemists, 1792-1895, and one of the seven presidents of the academy in that era. This offers insight into many of the scientists who were contemporaries of Poggendorff. *Paul R. Jones, University of Michigan.*

La Revolución Química. Entre la Historia y la Memoria (Reviewer's translation: *The Chemical Revolution. Between History and Memory*). Jose Ramón Bertomeu Sánchez and Antonio García Belmar, Publicacions de la Universitat de València, Valencia, 2006, 296 pp, ISBN: 978-84-370-6549-6. The book is published in Spanish.

The title of the latest collaboration between Profs. Bertomeu Sánchez and García Belmar (1) tacitly reveals the question that lies behind their account of the events of the chemical revolution: why is the chemical community's *memory* of the chemical revolution at odds with the *history* of the chemical revolution as has been described by academic historians? In seeking to answer this question, the authors weave a narrative that attempts to serve as a specific example of the tendency of disciplinary scientists to view the birth of their discipline as a heroic-mythical event (a genius creates chemistry from nothing) against the more nuanced and analytical descriptions of historians. In the particular example of chemistry, the question stated above could also be phrased as follows: why has the chemical community come to possess a *distorted* view of the historical events of the chemical revolution and still believes that chemistry started with the chemical revolution that Lavoisier alone marshaled? For the authors, the existence of these historical errors is a pleasantly convenient excuse to write a revision of the chemical revolution which, as

a welcome side effect, might contradict the mistaken belief that there was no chemistry before Lavoisier, and that his revolutionary ideas were the result of his mind alone. Indeed, the bulk of the book does not address the reasons for the existence of misconstrued historical notions in the chemical community, as the question above remains suspended until the last chapter of the book. The remaining seven chapters take up a reexamination of the experiments that formed the chemical revolution, a description of the chemical community before and after the chemical revolution, and a compilation of the responses of the chemical community of the time to the experimental work of Lavoisier.

The richness of the historical period that is covered does not allow for an exhaustive treatment in the 250 pages that comprise the body of the narrative. Instead, choices have to be made, and the historical vignettes described by the authors were selected with the intention of eliminating the vision of the chemical revolution as an event that radiates exclusively from Lavoisier's discoveries (*memory* of the chemical community), to one that flows naturally from the early work of the alchemists and the phlogiston theory of Becher and Stahl (*history*), and where the agency of the discoveries is transferred from one sole genius to the plurality of the chemical community. As it is pointed out in the bibliography, there are few works that provide an account of the chemical revolution along the revisionist ideas stated above, and, as such, this is a welcome addition to the scholarly lit-

erature. Lesser known agents of the chemical revolution are emphasized throughout, thus enriching the canonical historical narrative. On the other hand, the examination of participants whose actions were mainly a reaction to the main events of the chemical revolution requires a vigorous connecting effort that avoids the disintegration of each part of the book into a disjointed collage of seemingly separate historical episodes. At this potential pitfall, the authors only partially succeed, given their tendency to dwell on areas that are somewhat tangential to the main thrust of their stated purpose. It is difficult to understand the relevance of the otherwise fascinating travails of the Spanish chemist Juan Manuel de Aréjula, during an epidemic of yellow fever in Spain in the early 1800s, to the mechanism by which historical concepts about the chemical revolution were formed and disseminated. A minor blemish along these lines is also the diluting excess of detail in the illustration of certain passages. This is only a slight problem because it originates from the obvious erudition of Bertomeu Sánchez and García Belmar, and, while distracting, it is also instructive.

The history is recreated in chronological order, starting with the status of chemistry right before Lavoisier's time (Chapter 1). The carefully detailed passages in this chapter ably accomplish the difficult task of acclimating the reader to the repertoire of chemical ideas and problems of the time: combustion and metal oxidation and phlogiston as its answer, the composition of salts, and the beginnings of "pneumatic chemistry," when air ceases to be an element and acquires a multilayered structure. The authors convincingly and meticulously reveal that the scientist working on problems related to the structure and reactivity of matter in the 18th century operated inside what cannot be called by any other name than a scientific discipline: theories were examined experimentally and critiqued by peers who had attained entry into the chemistry community through professional channels (medicine, metallurgy, pharmacy) or an emerging formal academic instruction.

Chapters 2 and 3 recount, among others, the experiments that led to the law of conservation of mass, the release of oxygen from the pyrolysis of mercury oxide, and the synthesis and analysis of water. The narrative of these two chapters recreates the frenzied seminal events of the 1770-1790s with such exceptional levels of vividness that the entire book is overshadowed by this accomplishment. An entire scientific community is brought to life; its interactions through letters, public lectures, personal contacts, and scientific publications are punctiliously presented and their effects on the revolutionary

ideas of the time analyzed. The treatment of Lavoisier's work is quite exceptional as the authors' use of primary sources that analyze the laboratory notebooks of the French chemist enables them to present the thinking process of Lavoisier and the evolution of his own hypotheses in great detail. Reading about Lavoisier's doubts and uncertainties as he started to realize the inevitable transcendence of his experimental results—and how his data slowly undermined and eventually demolished the phlogiston artifice—brings to life the human dimension of an otherwise statuesque historical figure and helps to connect the contemporary scientific community with its own past. To be sure, a great deal of the trepidation that accompanies these historical events is in no small part due to the awareness these actors of the chemical revolution possessed about the consequences of their experiments. Lavoisier and his contemporaries knew there was a "before" and an "after," that they were living in an historical turning point; and they battled fiercely in order to ensure that their own notions (phlogiston or oxygen), as substantiated by experimentation, would survive. Lavoisier, Cavendish, and Priestley influenced each other through their work and engaged in intellectual, pugilistic reexaminations of their experimental data. Some of those encounters are described in the text and help to build the image of the chemical community as a multi-bodied entity, in which the most prominent characters are highly visible because of not only their inordinate intellect, but also because of their ability to stand on the shoulders of a creative and engaging community.

Unfortunately, the narrative becomes quite muddled during the description of experimental details, procedures, and results because of the authors' inexplicable decision to employ in the narrative only the chemical nomenclature of the 1700s (i.e., oxygen = dephlogisticated air). Although a moderately useful glossary follows the book, this is no substitute for the use of modern chemical terminology either exclusively, or in concert with antiquated terminology. The authors accurately predict the controversial nature of their choice and defend it by suggesting the possibility that modern nomenclature would cloud the correct interpretation of the experiments and the ideas being pursued by the scientists of the time; perhaps, but the dual use of ancient and modern terms would have maintained the historical rigor without any of the problems of interpretation. Incidentally, there are no chemical equations in the entire book.

After the chapters describing the actual events of the chemical revolution, the rest of the text is devoted to illuminating how the ideas of the chemical revolution

were received in the European chemical community of the time. Chapter 4 in particular examines the development of devices for the dissemination of the new ideas, including the advent of scientific journals. The journals that are covered in the text and which were partially or exclusively devoted to chemistry include *Observations sur la Physique, sur l'Histoire Naturelle et sur les Arts; Annales de Chimie* and *Journal de physique, de chimie et d'histoire naturelle*. The text focuses on *Annales* and *Journal*, and, in particular, the process of their founding, their role in the defense of a particular ideology (oxygen or phlogiston), and their underlying philosophy (conservative vs. adventurous).

The chemistry textbooks had to be rewritten after the chemical revolution. In this, Lavoisier took a personal stake; and, therefore, the influence of his chemistry textbook (*Traité élémentaire de chimie*) and his proposal for a new chemical nomenclature (*Méthode de nomenclature chimique*) are exposed to a critical eye. This analysis reveals the possible influence that older textbooks of Macquer and Baumé might have had on Lavoisier's own *Traité*, as well as aspects of the nomenclature work done by some of Lavoisier's predecessors (Macquer, Bergman, and Guyton de Morveau). As in the earlier chapters, this discussion succeeds at presenting Lavoisier as a transforming watershed of ideas and at detailing the historical peculiarities of the time: the authors' description of the idiosyncrasy of compound naming before publication of the *Méthode* is particularly revealing of the great challenges that one would face in characterizing matter when devoid of modern analytical instrumentation!

Chapters 5, 6, and 7 as a whole offer a cogent portrayal of the factors that influenced the manner in which the ideas of the chemical revolution were regarded by the European chemistry community of the early 19th century (partial or complete acceptance, rejection, or adjustment to one's own views). Chapters 5 and 6 dwell, respectively, on professional activity (specifically industry and medicine) and politics, whereas chapter 7 employs a mini biography of the Spanish chemist Juan Manuel de Aréjula to illustrate how the ideas of the chemical revolution flowed from its geographical epicenter (France) to a scientifically and geographically peripheral region (Spain). Professional activity and nationality were major determinants of the type of reaction to Lavoisier's ideas; for instance, while Swedish mineralogists acquiesced or simply ignored the fall of phlogiston (gases are not usually found among minerals and rocks), German academics were very eager to defend vigorously the theoretical construct of their German compatriot Stahl. The nomen-

clature proposals of the *Méthode* were not taken at face value, but were heavily edited according to the language and the culture of the national chemistry community (the direct translation of certain French terms would have had ludicrous meanings in the Spanish). In a phenomenon that is somewhat foreign to the modern international scientific community, the revolutionary agitation of the first half of the 19th century and the concurrent rise of nationalism did affect much of the behavior of the chemical community, especially because the chemical revolution prompted an interest in the creation of new academic spaces for chemistry instruction, which required that scientists enter the political arena. This is quite well exemplified in the life of Aréjula, an active revolutionary, who exiled himself in England after the restoration of the Spanish absolutist monarch Ferdinand VII in 1823. It is somewhat ironic that Lavoisier also served as a harbinger of prosecution when he was executed!

Finally, having fully explored the historical environment that impinged on the chemical community before, during and after the chemical revolution, in the last chapter of the book the authors move to address the question posed at the beginning of the text (why does the modern chemistry community have a distorted view of the chemical revolution?) (2) by compiling the origins of the historical misconceptions present in the chemical community. The authors present examples of the first historical accounts of the chemical revolution, as told by the contemporaries of Lavoisier and the generation directly thereafter. It is in these documents where the trouble begins, as they contain the premise that, briefly put, Lavoisier founded chemistry. This idea was easily propagated through time in commemorative speeches, and, more significantly, in chemistry textbooks, where the lack of space and the need to develop concepts according to pedagogy, not chronology, forced the simplification of historical detail. The final lines in the book reflect the authors' call for the establishment of spaces where the contrasting views of chemistry and history may be synchronized; this is done in the abstract and without concrete proposals.

The authors include a bibliography that not only precisely suggests where to go for further reading but also demarcates pretty well the scope of their own contribution. A website (www.uv.es/~Bertomeu/revquim) developed as an accompaniment to the book provides some quick reference background information on some of the main characters of the chemical revolution; parts of this site were incomplete as of 7/28/07.

In spite of the erudite and well articulated narrative that dominates the text, the book does possess some significant flaws. Some of these are simply factual (the stomach acid is said to be phosphoric acid (p 223) and the product of a chemical reaction is described as a “mixture of pure substances (p 120)”) and some are derived from incomplete editing (there are some spelling mistakes and at least two passages (pp 159 and 179) where earlier parts of the book are erroneously referenced). However, the most significant problems are of a scholarly nature. In a number of instances concepts are quoted from other primary sources without referencing (the authors simply speak of the source as “other historians”); and, in at least three cases (pp 36, 40, and 169), this misallocation of credit occurs when the quote refers to ideas contrary to the authors’ own. To be sure, some of these referencing problems are rectified in the bibliography, which also happens to contain a rather inappropriate statement: on p 268 the authors qualify one of the cited studies as questionable without bothering to recite the arguments that lead them to this judgment.

Another sticky point relates to the improper evaluation of the scientific concepts emanating from the chemical revolution with regard to their transcendence, eventual relevance, and utility. Whereas the authors are exceptionally qualified to recreate the historical setting of the chemical revolution and do present a satisfying narrative that could have helped redress the historical misconceptions of the chemical community, they seem woefully unable to evaluate satisfactorily the significance of the law of conservation of mass and the exceptional paradigm shift that the abolition of phlogiston represented. Indeed, these shortcomings could not only prevent this book from serving as the bridge between chemistry and history that the authors so persuasively argue for, but they could also overshadow what is a very carefully built work of dissemination of historical research.

For instance, in arguing that the chemical revolution was not the conflict between two different paradigms that Thomas Kuhn envisioned, the authors quote historical interpretations of the work of Lavoisier (p 237) which claim that the changes induced by the chemical revolution were limited to certain aspects of chemistry (combustion and oxidation), and that certain areas (plant chemistry) were almost entirely refractive to these changes. Indeed, not all the theoretical constructs that Lavoisier promulgated were entirely correct (his theory of acidity), or wholly relevant to all of chemistry (organic chemistry would not come of age until the end of the 19th century); but to quote these interpretations without the qualification that

absolutely all of the studies of matter will end up relying on the primordial law (not theory, law!) of the conservation of mass, or the proviso that Lavoisier accurately demonstrated that combustion is a *combination* and not the *decomposition* that phlogiston predicted, simply smacks of scientific illiteracy. To make things worse, the text invariably emanates a certain insensitivity on the part of the authors towards the scientific method and to the realities of experimental science: the actual realization of mass conservation by Lavoisier is belittled (p 239) because it was not found in a deliberate manner, but rather discovered as a tool to rationalize certain experimental results. How else was this supposed to happen in an environment where, as the authors point out, quantitative analysis was seen as irrelevant? It almost seems as if part of the problem lies in the authors’ conception of historical rigor as an imperative to give every faction of the chemical revolution an even hand, even if the scientific arguments indubitably and incontrovertibly tip the balance in favor of only one option. Under that light, it is easy to understand the authors’ unremitting unwillingness to criticize Priestley’s phlogiston as well as their tacit antagonism toward Lavoisier: Aldo Mieli is quoted as saying that it is very difficult to attribute a single original discovery to the French chemist. Of course, this depends on what is meant by “discovery.”

In summary, “*The Chemical Revolution. Between History and Memory*” successfully defends the view of chemistry as an endeavor that was well developed before the chemical revolution, an event which, in turn, is compellingly conceptualized as a collaborative effort (especially in the areas of terminology development and dissemination of the new ideas), where Lavoisier served as a transformative watershed. On the other hand, what the authors are due in *history*, they lack in *science*, and, as such, a wildly passionate reader may extend the deficiencies of the book to the entire text and overlook the important historical scholarship that is the most welcome portion of this new work. *Gorka Peris, Postdoctoral Associate, Department of Chemistry, Yale University, New Haven, CT 06511.*

1. The CV of Prof. Bertomeu (University of Valencia, Spain) (<http://www.uv.es/=bertomeu/pub/cv.htm>, accessed 7/28/07) lists Prof. Belmar (University of Alicante, Spain) as a regular coauthor in published articles and at least one other book.

2. It must also be said that there are no sources cited in the text that document the modern chemistry community’s understanding of the chemical revolution.

Chemistry, Medicine, and Crime: Mateu J.B. Orfila (1787-1853) and His Times. José Ramón Bertomeu-Sánchez and Agustí Nieto-Galan, Ed., Science History Publications, Sagamore Hill, MA, 2006, 331 pp, ISBN 0-88135-275-6, \$52.

It was not clear to me for whom this book was written: the chemist or toxicologist who wanted to know more about some aspects of the historical development of the origins and spin-offs from their disciplines, or the professional historian of science. Some 11 different authors have contributed papers describing the early 19th-century development of toxicology and forensic medicine. The papers only glue lies in their connection to the Spanish chemist Mateu Orfila's role in the development of toxicology and forensic science. Although the diversity of authors' topics does not lead to a totally engaging narrative, there is much to be learned. It was of interest to me to learn more about how the success of chemical analysis in the "inorganic" world stimulated

the experimental studies in the "organic" realm that led to the establishment of the discipline of medicinal chemistry. The development of toxicology was stimulated by the appearance of Mateu Orfila, Robert Christison, and other chemists who served as expert witnesses in place of physicians in a number of famous poisoning trials. Some of you analytical chemists might enjoy reading about the development of the Marsh test for the detection of arsenic, and consider whether you could qualify as an expert witness as to whether arsenic was present in sufficient quantities to confirm it as the poisoning agent. Many of the tests for poisons were often demonstrated on a variety of animals in Orfila's lectures on medicinal chemistry at the Paris Academy of Medicine. Orfila's main contributions to toxicology were summarized in his *Traité des poisons* (published in 1814) – which became one of the most popular and influential textbooks in the first half of the nineteenth century. *O. Bertrand Ramsay, Eastern Michigan University, Ypsilanti, MI.*

Chemistry, Decade by Decade. Arthur Greenberg, Info-base Publishing, New York, 2007, ISBN: 978-0-8160-5531-9, Hardcover, \$49.50.

Chemistry, Decade by Decade is part of *Twentieth-Century Science*, a seven-volume set that summarizes achievements in several core areas of science, including biology, chemistry, earth science, marine science, physics, space, astronomy, and climate. Each volume contains an extensive glossary and a list of additional reading sources, as well as time lines, biographies of scientists in the different areas, and some background for the science that is described. The series is meant to correlate achievements in a particular science with events in history, developments in technology, and progress in related scientific fields. One of the stated goals of the series is to teach "new explorers of the world the benefits of making careful observations, of pursuing paths and ideas that others have neglected or have not ventured

to tread, and of always questioning the world around them" (p xvii).

Greenberg states in the Introduction (p xxi) that the book is nonmathematical and, though geared for a general audience, would be best appreciated by those who have had some high school or college chemistry. He gives his area of expertise as organic chemistry, which is apparent in the preponderance of topics related to that subject. This is not to say, however, that other areas are neglected. The book includes material on all subsets of chemistry, as well as technology, manufacturing processes, related sciences such as biochemistry and genetics, and historical perspectives.

This book is helpful because of the niche it fills. Most standard textbooks for chemistry courses in high school or early college years include some historical information. There are often sidebars in these texts that

focus on the biography of a scientist or on an event or historical period. This book supplements that kind of material, enabling the teacher or student to relate the subject matter to other scientific discoveries and to the times in which the discoveries were made. While most teachers would like to incorporate such related information into their curricula, it is often difficult to find sources that are concise and informative. The internet is a useful tool in such quests, but it is also helpful to have a printed list of interesting and related subjects from which to select. That is what this book supplies.

To see how this is so, it might be helpful to look at Greenberg's treatment of two representative subjects: steroids and the development of nuclear weapons. Greenberg traces the development of steroids in some detail. He begins with the early work in bile acids and cholesterol (p 65), continues with the identification and structural analysis of cholesterol and sex hormones (p 127), and concludes with the total synthesis of steroids (p 200). The section "Chemistry and the Manhattan Project" (pp 169-171) describes the beginning of the project as a response to early German discoveries in nuclear energy. The idea of nuclear weapons under the control of Hitler was so terrible, that U.S. government officials cooperated with scientists in the private sector to initiate work on the atomic bomb. The section details the science of purification of nuclear fuels and shows how those fuels were assembled to make nuclear weapons.

Especially in today's world where the sciences intertwine, where technology plays such a critical role, and where events are so much a product of history, it is important for students to be aware of the relevance of the subject matter to their world.

Each chapter in *Chemistry, Decade by Decade* reviews developments in a separate decade, starting with 1900–1910 and concluding with 1990–2000. The early chapters also summarize relevant information from previous centuries. Each chapter begins with a timeline of milestones for the decade to be studied. This is particularly helpful because the individual achievements are often unrelated, and it is useful to be able to put them in a concise historical perspective. The many sidebars in the book include topic summaries and biographical sketches of individual scientists. Typical sidebars include those on "The Bhopal Disaster" (p 334) and "The Origins of the Mole and Avogadro's Number" (p 63). The first addresses chemical accidents, particularly the accidental release of methyl isocyanate in Bhopal, India, which caused the deaths of over 2,000 people. The

second describes various efforts to determine the value of Avogadro's number.

As the title suggests, *Chemistry, Decade by Decade* emphasizes time relationships. The book's timelines stress primarily chemistry-related events, but the body of the text includes many historical occurrences where chemistry played a part. For example, a section in Chapter 2, "World War I and Aftermath" (p 68) summarizes political events leading up to World War I and then traces the development of explosives and propellants, beginning with the Chinese invention of gunpowder in 1150. During World War I synthesis of cordite, a propellant used by the British, required acetone, which was in short supply at the time. A chemist, Chaim Weizmann, at the University of Manchester, developed a process to produce acetone. Rather than accept payment for his work, Weizmann, an ardent Zionist, pressed the British government for the Balfour Declaration, which supported the establishment of a Jewish state in Palestine. Weizmann eventually became the first president of Israel.

One of the most impressive features of the book is the scope of topics covered. A few general threads run throughout, including work on the periodic table and discovery of the elements, the environment, genetic engineering, instrumental analysis, and nanotechnology. For the most part, though, the various topics are diverse and generally unrelated, except for their place in history. Here is a sampling of subjects that suggests the range of material covered in the book: the Hubble Space telescope, the Murchison meteorite and the possibility of extraterrestrial amino acids, superconductors, the Manhattan Project, carbon dating, the double helix, polymers, transition elements, and pharmaceutical chemistry.

The titles of the individual sections within the chapters are well chosen, and the sections seem to be logically arranged. For example, a section on two-dimensional NMR spectroscopy is followed by one on applications of NMR to solids and to magnetic resonance imaging. *Chemistry, Decade by Decade* can function as a beginning reference book for these individual topics. Although some subjects are complex, Greenberg summarizes them concisely and makes them understandable. Many of the more difficult topics are in the author's area of expertise, organic chemistry (for example, proteins, organic mechanistic discoveries, and nanotechnology). In those areas, particularly, it would help the reader to have some initial familiarity with the subject.

Greenberg is true to his promise that his book would be math-free. There is a scattering of equations, but

they are dealt with mainly in a qualitative fashion. The many illustrations are relevant and helpful; they include schematic diagrams, illustrations of chemical structures, and pictures of mechanistic pathways. Each chapter ends with a list of resources for further reading, and the book itself concludes with a slightly longer list of the

same type, one that includes books and websites. Also at the end of the book, there is a glossary of chemical terms and their definitions, a list of Nobel Prize winners in chemistry, and a very extensive index. *Mary L. Wise, Ann Arbor, MI.*

Michael Polanyi: Scientist and Philosopher. William Taussig Scott and Martin X. Moleski, S.J., Oxford University Press, New York, 2005, ISBN 9780195174335, 364 pp, \$26.99.

The book provides a comprehensive biography of Michael Polanyi (1891-1976). Polanyi attained international stature as both a physical chemist and a philosopher. He was born in Budapest, Hungary. Following medical training and brief service as a doctor, he shifted his attention to the field of physical chemistry, carrying out important work on adsorption for his doctorate at the University of Budapest. Polanyi's scientific career blossomed in Berlin at the Kaiser-Wilhelm Institute for Fiber Chemistry (1920-1923) and Haber's Institute for Physical Chemistry and Electrochemistry (1923-1933).

Following the rise of totalitarianism in Central Europe, Polanyi moved to become Chair of Physical Chemistry at the University of Manchester in England in 1933. He continued with much of his research there, making important contributions in both experimental and theoretical areas in chemical kinetics. But increasingly (possibly motivated by observing the deteriorating situation in Europe) he became interested in economic issues and social science. In 1948 he took up a faculty position in Economics and Social Studies at Manchester. He ended his academic career as Merton Fellow at Oxford as a philosopher. He synthesized many of his thoughts and experiences into a personal and professional philosophy of epistemology and is known for several philosophical works, including *Personal Knowledge*.

From an early age, Polanyi's work was characterized by broad interests and a deep understanding of connections between intellectual endeavors. Largely unmentored in science, his insights are strikingly original. He possessed the great gift of being able to transmit his vision with great clarity, both in his science and his philosophy. A picture emerges of a man of restless intellect, never quite satisfied with what he had achieved and always moving on to pioneer new areas.

Michael Polanyi is perhaps best known today in scientific circles for his seminal contributions to chemical kinetics and to the field now known as reaction dynamics. This work, exploring the connection between phenomenological kinetics and molecular structure and motions, led to several pioneering insights into the nature of the transition state. It is in this area that Polanyi's son, John, received the Nobel Prize in Chemistry in 1986.

In addition, Polanyi carried out significant work in crystallography and structure analysis. One deep insight from this field was the concept of "edge dislocations" in material science, where mismatches in the atomic lattice manifest themselves as strains in the bulk. In the early 1920s Polanyi inferred from crystallographic measurements that species such as cellulose will have anomalously high molecular weights. This was a controversial conclusion before the covalent structure of macromolecules was fully accepted.

The first author of this biography, William Scott, was trained as a physicist. Later in his career he developed a strong interest in Polanyi's philosophical ideas and spent considerable time with his subject. According to the book's preface, Scott was responsible for assembling most of the biographical material. Scott passed away in 1999, leaving the work in unedited form. Martin

Moleski, a professional philosopher, took over Scott's work, shaped the narrative, and is responsible for the final version of the book.

The biography follows Polanyi's life and career with impressively documented detail. The authors had access to Polanyi's letters and talked extensively with many of his family and contemporaries. The book contains extensive notes, a comprehensive bibliography, and a good index. The story is told chronologically; Polanyi's trajectory from scientist to social scientist to philosopher is carefully mapped, and it is shown how his personal and professional experiences inform each step of his journey.

The book is well written, with a strong sense of the sweep of history as the story moves through dictatorship in Europe, two world wars, and the paranoia of the cold war. The latter part of the book reads particularly well, and seems (to this chemist reviewer) to have a good feel for the ideas and personalities shaping social science and philosophy in the period from about 1930 to 1976. Unfortunately, the earlier, more scientific portion of the book is slightly less satisfactory. Explanations of Polanyi's scientific achievements are undertaken but are sometimes clumsily worded and frequently not given in the language most chemists will be familiar with. In addition, there are numerous typographical errors (such as "8" instead of "∞" [several times], "van der Walls" rather than "van der Waals," "hydrogen bromine" rather

than "hydrogen bromide," "C₁₂" rather than "Cl₂"). While these errors are themselves mostly minor distractions, they underline the fact that the narrative in the early part of the book lacks the insight into the "big picture" which characterizes the second half.

This is a shame. Physical chemistry in the early years of the twentieth century was an exciting emerging discipline, stimulated by the revolutionary ideas developing in physics. Polanyi was involved in many of the pivotal discoveries that shaped modern physical chemistry. Many of his insights were not fully appreciated in his time, and a critical reassessment of his contributions to the field is probably in order. A valuable complement to the scientific background given in this biography is Mary Jo Nye's essay "Laboratory Practice and the Physical Chemistry of Michael Polanyi" in F. L. Holmes, and T. H. Levere, Ed., *Instruments and Experimentation in the History of Chemistry*, MIT Press, Cambridge, MA, 2000. Her paper gives technical background for Polanyi's work in crystallography and places it expertly in scientific and historical context.

In conclusion, despite some slight weaknesses in the scientific writing, this biography presents an outstanding portrait of the life and career of Michael Polanyi and the times he lived through. It will be an invaluable reference work for those interested in this fascinating man. *Howard R. Mayne, University of New Hampshire.*

Chemical History. Reviews of the Recent Literature. C. A. Russell and G. K. Roberts, Ed., Royal Society of Chemistry, Cambridge, UK, 2005, hardcover, 229 pp, ISBN 0-85404-464-7, £59.95.

This collection of highlights from recent literature on chemical history, edited by C. A. Russell and G. K. Roberts, former editor of *Ambix*, is a sequel to Russell's earlier endeavor [C. A. Russell, Ed., *Recent Developments in the History of Chemistry*, Royal Society of Chemistry, London, 1985]. The title holds for all except a newly introduced chapter on physical organic chemistry, which covers literature from 1907 up to the time of this publication. With that exception, each chapter

is intended as an update of literature published in each specific subject since 1985.

The introductory chapter, "Getting to Know History of Chemistry," is written by the two editors. They present a perspective on how the scholarly approach to the history of chemistry has changed in the last few decades. More work is being published by professional research chemists rather than historians of science. As the authors point out, this was the case in the mid-19th century, when eminent chemists such as Hermann Kopp created invaluable treatises on chemical history.

There follows a presentation of "Chemistry before 1800" (Chapter 2); then Chapters 3-8 cover, respectively, inorganic, organic, physical organic, physical, analytical, and medical chemistry and biochemistry. All are

written by other historians, except for the chapter on organic chemistry by Russell. The final Chapter 9 is titled "Instruments and Apparatus." One might have expected chapters devoted to industrial and environmental chemistry, inasmuch as these topics are prevalent in current scholarly work.

Unlike the case with the 1985 book, the authors have employed a computerized search program and note this approach allowed uncovering far more publications than would have been realized otherwise. It would be impossible to assess the comprehensiveness of these searches, without carrying out a parallel one; but omissions are inevitable. As an example, in the subsection on "Chemical Biographies" in Chapter 2 there is no mention of the long overdue biography of Wöhler [R. Keen, J. Büttner, Ed., *The Life and Work of Friedrich Wöhler* (1800-1882), Verlag Traugott Bautz, GmbH, Nordhausen, 2005]. While this is being singled out as an important citation, its omission may have been a matter of publication deadline. In Chapter 2 the editors acknowl-

edge the drastic change in sources since publication of the earlier 1985 book, because of the advent of the internet. They justifiably raise the question of the reliability of material from secondary—and often—undocumented online sources. No specific mention is made of current periodicals where papers in the history of chemistry are most likely to appear.

Literature citations are provided at the end of each chapter. Their number is deceptively large, however, because the authors duplicated identical references when they were cited more than once in the text. The Subject Index seems sparse for such a large collection of references. Entries in the name index are limited to those specifically mentioned in the text. An alphabetical listing of all the authors would have provided an invaluable bibliography for readers. This book, the manifestation of a massive, exacting undertaking, will serve as a dependable source for historians of chemistry in those areas that have been covered. *Paul R. Jones, University of Michigan.*



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1. O. T. Benfey, "Dimensional Analysis of Chemical Laws and Theories," *J. Chem. Educ.*, **1957**, 34, 286-288.
2. G. W. Wheland, *Advanced Organic Chemistry*, Wiley, New York, 1949.
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