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WHAT A WONDERFUL EMPIRE IS THE ORGANIC CHEMISTRY*

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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.

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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.

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,

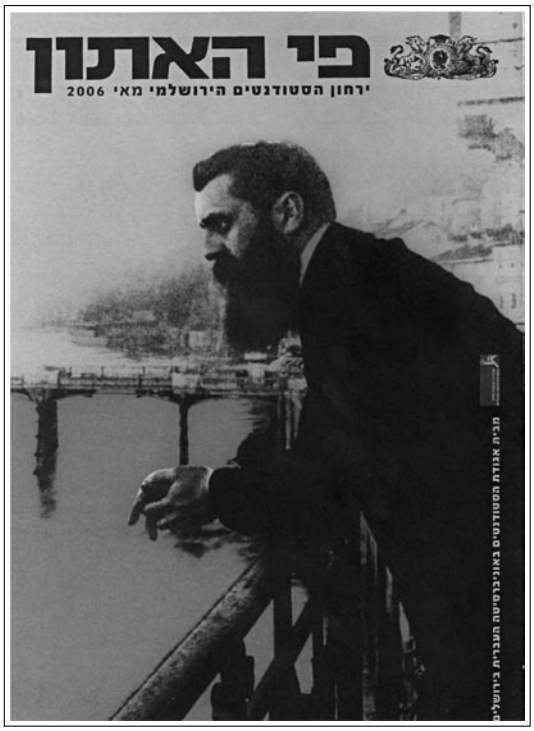

Figure 1. *Theodor Herzl on the balcony of the Three Kings Hotel, Basel, in December 1901. From a photograph by Ephraim Moses Lilien. Edelstein Collection.*

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.

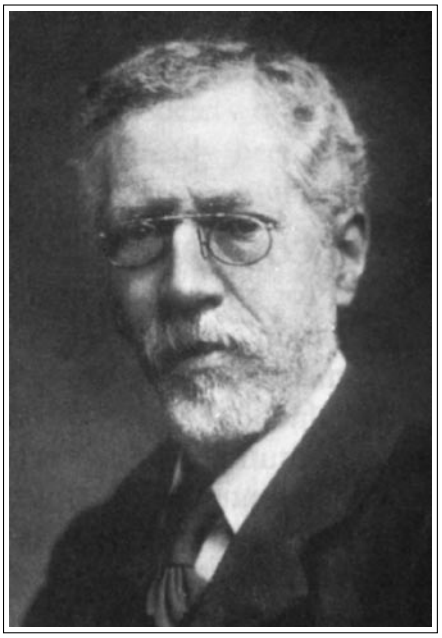

Figure 4. *Heinrich Caro (1836-1910). BASF Corporate Archives, Ludwigshafen/Rhein.*

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.

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

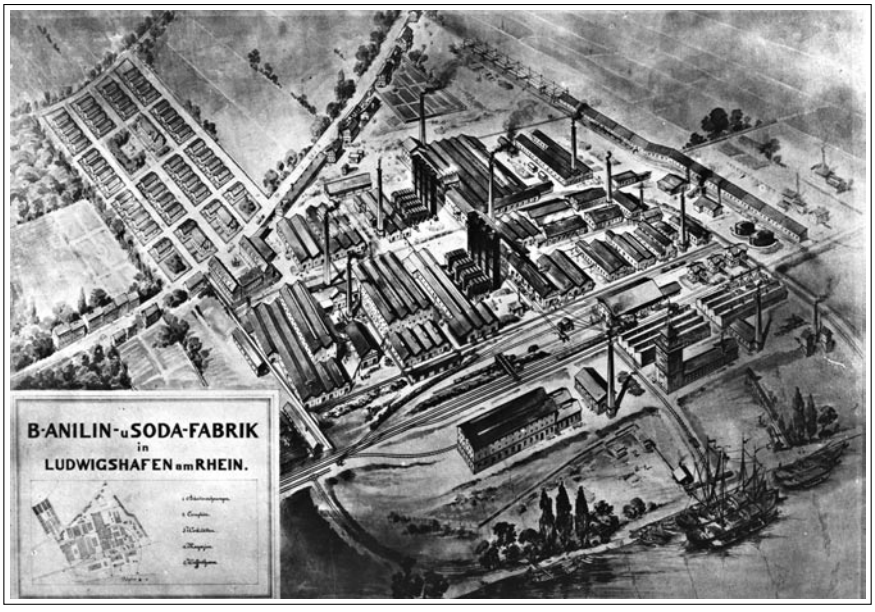

***Figure 5**. BASF factory, Ludwigshafen, around 1890. Edelstein Collection.*

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

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

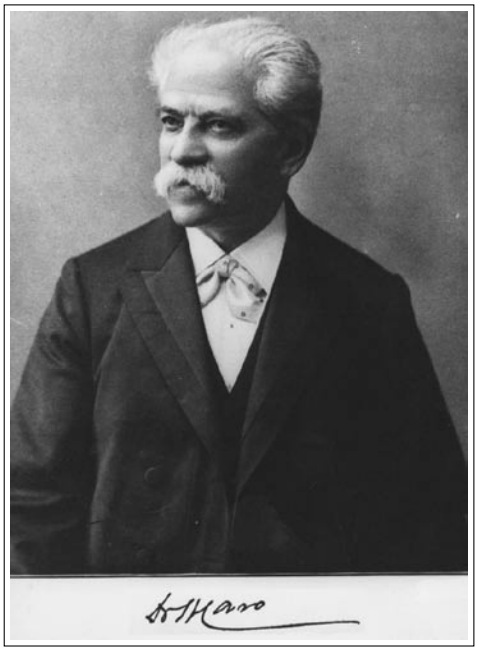

***Figure 6**. Raphael Meldola (1849-1915.) Edelstein Collection.*

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 chrysaniline 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 indigo. 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.

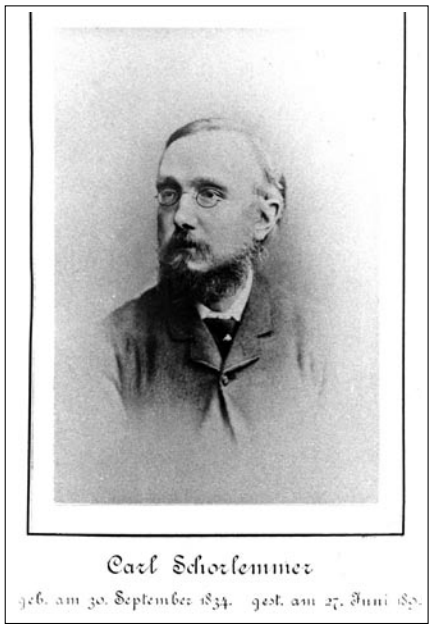

Figure 7. *Carl Schorlemmer (1834-1892.) Edelstein Collection.*

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.

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REFERENCES AND NOTES

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1. Recent contributions to the literature include: H. van den Belt, E. Homburg, and W. J. Hornix, Ed., *Development of the Dye Industry*, University of Nijmegen, 1985; E. Vaupel, Carl Graebe (1841-1927): Leben, Werk und Wirken im Spiegel seines brieflichen Nachlasses, Ph.D. dissertation, 2 vol., University of Munich, 1987; E. Homburg, "The Emergence of Research Laboratories in the Dyestuffs Industry, 1870-1900," *Brit. J. Hist. Sc.*, **1992**, *25*, 91-111; A. S. Travis, *The Rainbow Makers: The Origins of the Synthetic Dyestuffs Industry in Western Europe*, Lehigh University Press, Bethlehem, PA, 1993; K. Steen, Wartime Catalyst and Postwar Reaction: The Making of the United States Synthetic Organic Chemicals Industry, 1910–1930, Ph.D. dissertation, University of Delaware, 1995. UMI Microfilm no. 9610494 (1996); C. Reinhardt, *Forschung in der chemischen Industrie. Die Entwicklung synthetischer Farbstoffe bei BASF und Hoechst. 1863-1914*, Technische Universität Bergakademie Freiberg, 1997; S. Garfield, *Mauve: How One Man Invented a Colour that Changed the World*, Faber and Faber, London, 2000; C. Reinhardt and A. S. Travis, *Heinrich Caro and the Creation of Modern Chemical Industry*, Kluwer, Dordrecht, 2000; S. B. McGrayne, *Prometheans in the Lab: Chemistry and the Making of the Modern World*, Mc Graw-Hill, New York, 2001, 15–29; J. P. Murmann, *Knowledge and Competitive Advantage: The Coevolution of Firms, Technology and National Institutions*, Cambridge University Press, Cambridge, 2003; A. S. Travis, *Dyes Made in America, 1915–1980: The Calco Chemical Company, American Cyanamid, and the Raritan River*, Edelstein Center/Hexagon Press, Jerusalem, 2004; special edition of *History and Technology*, June **2006**, *22*; A. S. Travis, "Anilines: Historical Background," in Z. Rappoport, Ed., *Patai Series. The Chemistry of the Functional Group: the Chemistry of Anilines*, Wiley, Chichester, Vol. 1, 1-73; A. S. Travis, "Mauve and its Anniversaries," *Bull. Hist. Chem.*, **2007**, *32*, 35-44. See also corporate histories, including: E. Verg, G. Plump, and H. Schultheis, *Milestones: The Bayer Story. 1863–1988*, Bayer AG, Leverkusen, 1988; W. Abelhauser, W. von Hippel, and J. A. Johnson, *Die BASF: Von 1865 bis zur Gegenwart. Geschichte Unternehmensgeschichte*, C. H. Beck, Munich, 2002 (in English translation, *Germany, Industry and Global Enterprise. BASF: The History of a Company*, Cambridge University Press, Cambridge, 2003).
2. M. Narkiss, "The Arts Portray Herzl: A Description of the Many Forms in which Herzl is Remembered," in M. W. Weisgal, Ed., *Theodor Herzl. A Memorial*. The New Palestine, New York, 1929, 119-120.
3. T. Herzl, "Das Wirtshaus zum Anilin," in his *Philosophische Erzählungen*, Gebrüder Paetel, Berlin, 1900, 233-244.
4. "Das Wirtshaus zum Anilin," is reproduced in full in *Das lenkbare Luftschiff. Philosophische Erzählungen von Theodor Herzl*, Lösch Verlag, Speyer, 2004.
5. "Production of Aniline Colours in Germany," *J. Soc. Arts*, June 5, **1874**, *22*, 698.
6. C. Reinhardt and A. S. Travis, *Heinrich Caro and the Creation of Modern Chemical Industry*, Kluwer, Dordrecht, 2000.
7. W. Smith, "International Inventions Exhibition London. Report on the Exhibits Relating to the Chemical Industries," *J. Soc. Chem. Ind.*, **1885**, *4*, 469-83 (479).
8. E. F. Ehrhardt, "Reminiscences of Dr. Caro," *Chem. Ind. J. Soc. Chem. Ind.*, **1924**, *43*, 561-65 (561-62).
9. H. Caro, "Ueber die Entwickelung der Theerfarben-Industrie," *Ber. Dtsch. Chem. Ges.*, **1892**, *25*, 955-1105 (957-58).
10. Ref. 9, p 960.
11. Johnson to Caro, October 23, 1898, and August 7, 1899, Caro Nachlass, Deutsches Museum, NL93.
12. A. S. Travis, "German-Jewish Chemists and Raphael Meldola: The 1906 Jubilee Celebration for the Discovery of the First Aniline Dye," in U. Charpa and U. Deichmann, Ed., *Jews and Sciences in German Contexts: Case Studies from the 19th and 20th Centuries*, Mohr Siebeck, Tübingen, 2007, 51-75.
13. R. Meldola, "The Scientific Development of the Coal-tar Colour Industry," *J. Soc. Arts*, May 28, **1886**, *34*, 759-771.
14. E. B. Poulton, in J. Marchant, Ed., *Raphael Meldola: Reminiscences of his Worth by Those who Knew Him Together with a Chronological List of his Publications*, Williams and Norgate, London, 1916, 78-112.
15. R. Meldola, "Are Monkeys Quadrumanous?" *Land and Water*, February 4, **1871**, *11*, 91.
16. R. Meldola, "Mimicry in the Insect World," *Land and Water*, May 6, **1871**, *11*, 321-2.
17. H. Spencer, *Principles of Biology*, Williams and Norgate, London, 1864-1867, Vol. 1, 444.
18. M. W. Taylor, *Men Versus the State: Herbert Spencer and Late Victorian Individualism*, Oxford University Press, New York, 1992.
19. H. Spencer, *The Man Versus the State*, Williams & Norgate, London, 1884. Following Spencer's death in 1903, Meldola lobbied for a plaque or other memorial to be erected in Westminster Abbey, though it was ultimately rejected by the Dean of Westminster, mainly because of Spencer's avowed agnosticism. H. Gay, "No 'Heathen's Corner' Here: The Failed Attempt to Memorialize Herbert Spencer in Westminster Abbey," *Brit. J. Hist. Sc.*, **1998**,

31, 41-54.
20. Ref. 6, pp 308-312.
21. Meldola to Caro, November 6, 1885, Caro Nachlass, Deutsches Museum, NL93.
22. Ref. 13, p 762.
23. Ref. 13, p 769.
24. R. Meldola, "The Scientific Development of the Coal-tar Colour Industry," *J. Soc. Dyers and Colourists*, June 25, **1886**, *2*, 95-101.
25. Caro to Meldola, June 8, 1886, Meldola papers, Imperial College Archives, London, MLDA1812, in scrap book, p 33.
26. T. O. Benfey and A. S. Travis, "Carl Schorlemmer: The Red Chemist," *Chem. Ind. (London)*, June 15, **1992**, 441-444.
27. C. A. Schorlemmer, *The Rise and Development of Organic Chemistry*, rev. ed., A. Smithells, Macmillan, London, 1894, 240-251.
28. Gabor Pallo, personal communication to author.
29. H. Spencer, *First Principles*, Williams & Norgate, London, 6th ed., 1904, 222.
30. M. Forter, *Farbenspiel: Ein Jahrhundert Umweltnutzung durch die Basler chemische Industrie*, Chronos Verlag, Zürich, 2000; A. S. Travis, *Dyes Made in America, 1915–1980: The Calco Chemical Company, American Cyanamid, and the Raritan River*, Edelstein Center/Hexagon Press, Jerusalem, 2004

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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.