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August Wilhelm Hofmann—"Reigning Chemist-in-Chief"**

By Christoph Meinel*

One hundred and twenty-five years ago, on November 11th, 1867, the German Chemical Society of Berlin held its inaugural meeting. The main purpose of the Society was to unite pure and applied chemistry and to foster cooperation between academic research and the chemical industry. And, indeed, it soon became the major forum of German and even European chemistry. Its program clearly bears the hallmark of a single individual: August Wilhelm Hofmann, the Society's first president, who died 100 years ago. For his contemporaries, Hofmann represented a new type of chemistry professor. At no time since have professional chemists felt as abundantly endowed with potential for the future and with public esteem. Hofmann's portrait was monumental even then, and still today it would belong in any gallery devoted to our distinguished forebears.

Anniversaries provide an opportunity to direct our attention toward the past—and thus to ourselves as well. We are, after all, heirs to that period from which the modern world derives its profile. Questions from our own time lead us to reacquaint ourselves with one of the founders of modern chemistry, but we may also benefit from a fresh look at an epoch which, beneath the surface of prosperity and progress, was as contradictory as our own, an epoch struggling to understand the role of science in the new industrial era.

In Liebig's Laboratory

We must envision the young Hofmann as a sensitive individual, rather inclined toward literature and the arts—and the direct opposite of someone with a clear plan for the future.[1] He was stamped with impressions gathered in educational travel, especially to Italy, where the boy was accompanied by his father, Johann Philipp Hofmann, privy councillor and provincial architect to the court of Darmstadt. "This awakened his early interest in the study of modern languages and a certain facility for expressing himself in tongues other than his native German, a factor not without its influence on his later career."[2] Hofmann registered as a student in his native city of Giessen at the age of eighteen. His father would have liked to have seen him study architecture, but the son found himself drawn rather to languages, "an idea contested vigorously by the father on the grounds that it could not lead to any satisfactory goal." The resolution of this dilemma was a decision in favor of law, a study "to which the next few years were dedicated, with occasional interruptions and little notable success." As far as the pursuit of a utilitarian education was concerned, Hofmann found it difficult to develop any enthusiasm, "always wavering between philology, law, and even architecture." In those days, preparing oneself to become an administrative official included learning the fundamentals of chemistry, so Hofmann became acquainted with the basic tenets of analytical chemistry in Liebig's laboratory. The name Liebig was already on

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[**] This essay appears here as a preprint from *Die Allianz von Wissenschaft und Industrie: August Wilhelm Hofmann (1818–1892)-Zeit, Werk, Wirkung* (Eds.: C. Meinel, H. Scholz), VCH, Weinheim, November **1992**. In this volume, historians, historians of science, and chemists from industry and academia discuss Hofmann's life and work in the context of the society and economy of his time. They also trace those traditions that led to today's chemical research. The authors of this bilingual volume come from Germany, Great Britain, the USA, Czechoslovakia, the Netherlands, and Israel.

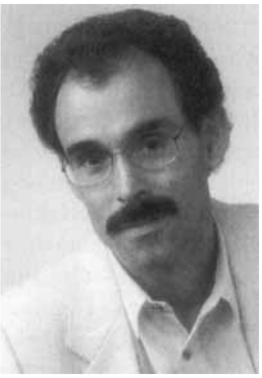
every tongue—his novel didactic methods had in fact attracted students to Giessen from all over Europe. It had already been necessary to expand the facilities of Liebig's institute on two occasions, and even to open a second branch, with construction activities carried out under the supervision of Hofmann's father. The resulting frequent—indeed, friendly—interchange between Herr Hofmann and Liebig was not without its effect on the son. According to one anecdote, Hofmann's father was moved to provide Liebig with an account of his son's indecisiveness and lack of academic success, to which Liebig is supposed to have responded: "give him to me, and I'll see what can be made out of him; he's a good lad, and he's certainly no fool; perhaps he just hasn't found the right path."[3]

> *Once within the sphere of attraction of the great master, he soon felt an irresistible pull toward the natural sciences, which confronted him with the lure of the novel in contrast to the singular course of his own previous studies. Thus began a new life, the study of law forgotten, philology relegated to the leisure hours, and the major part of his efforts dedicated to the study of chemistry, physics, and finally mathematics. Soon we see the young man working as a zealous pupil in the laboratory and ultimately taking part as an assistant in the research of the revered professor.*[4]

Liebig's institute in Giessen is regarded as the prototype of the modern university laboratory. Here experimental research became incorporated directly into the educational function of the university, and laboratories were transformed into work stations dedicated to the production of new knowledge. It was also here that the idea of a division of labor was first applied to research activities, with distinctive roles assigned to the group leader, one or more assistants, and the research students. Moreover, contacts were established between university research and industry, and the organizational form of the university "institute" as a large-scale enterprise had its beginnings. It all began with a single piece of methodology: the elemental analysis of organic compounds, which was developed to the level of a routine procedure in 1832. This proved the key to organizing research along new lines: "turning out the most audacious discoveries in a factorylike fashion," as Liebig once described it.[5] These were also decisive years for the discipline of chemistry itself. Organic and physiological chemistry emerged from the context of "plant and animal chemistry" as distinct fields of research. Fundamental concepts, the notions of elements and molecules, nomenclature and formulas: all demanded clarification. The question of chemical "vitalism"—which was supposed to provide a distinction between the "organic" and the "inorganic"—was transported into the realm of experimental answers. Commercial applications promised to furnish the discipline with improvements in obsolete techniques in addition to attractive profits.

Liebig's recipe for success included introducing his gifted students to research at a very early stage.[6] There was no such thing as a fixed curriculum, and passing an oral examination was the sole requirement for a doctorate. Outstanding performance on the latter, as in Hofmann's case, constituted grounds for certification as a qualified university lecturer *(Habilitation)*. Within a very short time we find Hofmann working as an assistant, and entrusted with editing the *Annalen der Chemie und Pharmacie*. His own first research results appeared in this journal in 1843 under the title "Chemische Untersuchung der organischen Basen im Steinkohlen-Theeroel" ("Chemical Investigation of the Organic Bases in Coal-Tar Oil").[7]

How often does it happen that a young chemist takes on as his first research topic a substance that will become the basis for his later fame—and for an entire industry as well? And how often does he succeed at the same time in locating a substrate open to almost infinite variation? The owner of a tar distillery in Offenbach, himself a former student of Liebig, sent a sample of the material to Giessen for analysis, and Hofmann was assigned the task of its investigation. He found in this tar two previously described bases, known as "kyanol" and "leukol" [quinoline],[8] and after a great deal of effort extracted from it sufficient material to demonstrate that the "kyanol" was actually identical to substances also characterized in the literature as "krystallin," "benzidam," and "anilin." Moreover, he showed that it bore a relationship to phenol, one which could be expressed in terms of the common radical "phen" or $C_{12}H_{10}$ [C = 6]. Shortly thereafter it became apparent that the other base, "leukol," was identical to Gerhardt's quinoline. The latter was of considerable interest as a degradation product of quinine. Once Hofmann succeeded in obtaining larger quantities of aniline from the benzene in coal tar, he subjected it to nitration and subsequent reduction with zinc in acid, after which he began



Christoph Meinel, born in Dresden in 1949, studied chemistry in Marburg. After receiving his Diplom, he turned toward the history of science and completed his Ph.D. in 1977 with a dissertation on the history of chemistry. Following a postdoctoral year at the University of Kent at Canterbury, he held positions at the Universities of Marburg and Hamburg and conducted research in the United States. In 1987 he completed his Habilitation in the field of history of science in Hamburg. He was Fellow at the Institute for Advanced Study, Berlin, in 1987/88, and later Heisenberg Fellow of the Deutsche Forschungsgemeinschaft and coordinator of the Verbund für Wissenschaftsgeschichte in Berlin. In 1990 he was appointed professor for history of science at Mainz but moved on to a chair for history of science at the University of Regensburg that same year. Since 1990 he has been chairman of the History of Chemistry Group in the Gesellschaft Deutscher Chemiker. His research interests include 18th- and 19th-century chemistry and early modern natural philosophy and theory of matter. He has published books on the history of chemistry at the University of Marburg, on the work of the 17th-century Hamburg naturalist and philosopher Joachim Jungius, and on the history of alchemy.

a systematic investigation of the various transformations. Indigo attracted his attention in this context, since it also led to aniline upon alkali fusion. A paper describing the properties of this dye[9] served as impetus for the preparation of its halogenated derivatives, in analogy to the chloro and bromo derivatives of isatin.

The matter proved to be of considerable interest. Accepted theory—in the Liebig school as elsewhere—held that a chemical compound should be regarded as a pairing of a stable, electropositive group of atoms, the "radical," with an electronegative element or group. It was recognized in the meantime, however, that an organic radical might incorporate electronegative elements like chlorine or bromine without altering its electropositive character. This observation was the starting point for a new "substitution theory," put forward and defended by Laurent and Dumas. The substitution theory made it possible for the first time to regard a molecule as a single entity, in which individual atoms might be replaced by other elements without fundamentally changing its chemical nature. This theory, championed by Liebig's bitterest opponents, had been the subject three years earlier of a malicious piece of satire formulated by Wöhler and Liebig and published in the *Annalen* under the pseudonym S. C. H. Windler ("swindler"). The alleged author reported that, thanks to the new French doctrine of "types and substitution," he had succeeded in replacing, one after another, all the atoms in cotton by chlorine, and that there was no significant change evident in the material's characteristics. Indeed, clothing manufactured from "spun chlorine" was said to be already on the market in London, where it was avidly sought by consumers! Was Liebig now expected to allow Hofmann's bromo- and chloroanilines to reignite this old controversy?

Facts

Hofmann must have known that he could never come to Liebig with a new theory. This was especially true since his mentor's research program had just recovered from a very serious crisis. Its origin can be traced to nearly insurmountable difficulties presented by the chemistry of nitrogen metabolism in animals. Liebig had struggled for a decade with the explanation for this phenomenon, using all the means available from a contemporary perspective. If chemistry were to satisfy the demands of the neo-humanist interpretation of science then it must demonstrate its powers in the context of a theoretical interpretation of natural phenomena.[10] And now his program was threatened with failure because of the complexity of the subject! The dilemma could only be resolved in one of two ways. Either the discipline must succeed in breaking new ground and convincingly translate its insights into practical results, thereby displaying to the world the utility it claimed to possess, or else the demand for a scientific interpretation of nature must be reduced to "hard" numbers and facts, with studious disregard for any speculative elements.

Hofmann chose the second path, adopting a compromising stance with respect to those aspects of his research that impinged upon bonding theory. Thus, while he acknowledged that hydrogen had been replaced by halogen, he emphasized at the same time the fact that the introduction of increasing amounts of bromine or chlorine caused the electrochemical character of the radical to be displaced in an electronegative direction. This left Liebig free to present this work in a footnote—not as evidence supporting the views of Dumas, but as a strike against Berzelius. Hofmann's own reserved attitude with respect to broad generalizations and theories is also apparent from the fact that he coupled his cautious compromise proposal with an express warning: "Nothing is more dangerous than attempting to draw general conclusions without the ability to stand on a mass of facts."[11] And when he submitted the work in a competition sponsored by the Société de Pharmacie in Paris, he took steps to ensure that he would not be accused of taking sides in the bonding theory controversy by adding the motto of the English author Edmund Burke: "Facts are to the mind what food is to the body."[12]

As it happens, this motto reveals to us one of the important characteristics of Hofmann's approach to research. To a much greater extent than most of his contemporaries, and comparable in this respect only to Wöhler, Hofmann avoided becoming involved in controversies surrounding the fundamental theories of chemistry. His papers speak instead the dispassionate language of "chemical facts." When confronted with the need to adopt a text for use in his classes in London, Hofmann chose to translate Wöhler's *Beispiele zur Übung in der analytischen Chemie* (Göttingen, 1853), a work that progresses through 122 chapters—very pragmatically, without any theory—proceeding from simple materials to complex situations involving applications. The translator's preface leaves no room for questioning the motive behind his choice: "General statements, general instructions, will always remain more or less unintelligible to the student, as long as he fails to have a sufficient number of facts at his disposal."[13] Thomas Gradgrind, director of the model school in *Hard Times*, would have taken a great deal of satisfaction from this textbook, which was published in precisely the same year as Charles Dickens' famous critique of the impending machine age, with its obsession for numbers and facts—a book that begins with the classic enjoinder: "Now, what I want is, Facts. Teach these boys and girls nothing but Facts. Facts alone are wanted in life. You can only form the minds of reasoning animals upon Facts: nothing else be of any service to them ... Stick to Facts, Sir!"[14]

Four years later, at the suggestion of Kekulé, chemists from all over the world assembled in Karlsruhe in an attempt to clarify the fundamental uncertainties surrounding the concept of atoms and molecules. Hofmann's was among the 45 signatures on the invitation, but he chose, in fact, not to make a personal appearance at this first congress of chemists. While others were publishing ambitious theoretical compendia, such as Kekulé's *Lehrbuch der organischen Chemie* (Erlangen, 1861–1887), Hofmann produced only a single small volume, almost conversational in style, entitled *Einleitung in die moderne Chemie*. This work does testify to his "conversion to 'Gerhardtism'"[15] and to the "types" notation, but otherwise maintains a very pragmatic tone, with commitment to clear, didactic presentation and to "extreme moderation, the most measured reserve"[16] with respect to theory. The most original part of the work—a computational method based strictly on gas volumes ("Krithen") rather than mass units, with the corresponding formulas expressed graphically—was never copied by anyone else, and must have seemed, only six years after the Karlsruhe congress, oddly positivistic. When the sixth and last edition of the *Einleitung* appeared in 1877 it still contained no reference whatsoever to the periodic table, and the list of atomic weights of the elements is simply presented alphabetically! And yet, Hofmann was anything but "A man of realities, a man of facts and calculations" in the mold of Gradgrind. Precisely the tension arising between the bold geometrical speculations of a Kekulé or a van't Hoff and the massive production of tangible "chemical facts" by a Hofmann, the latter outrunning every theory—it is this dichotomy that explains the incredible dynamic of chemistry at that time.

What Marvelous Opportunities!

Giessen offered no place for Hofmann over the long term. Assistants with greater seniority had priority in terms of acquiring a professorship. Liebig played his cards close to the chest when it came to personnel matters. Consequently, Hofmann cleverly contrived during the master's absence to become engaged to his niece, at the same time transferring his activities to Bonn. Understandably enough, Liebig was "painfully moved" to discover that his protégé had seized the initiative "without consulting me and without telling me about it," in the process frustrating his own plan for establishing Friedrich Mohr in the Bonn position, which had already been proposed to him.[17] In the spring of 1845 Hofmann became a *Privatdozent* (instructor) in Bonn. What he had in mind was nothing less than establishing a copy of the successful Giessen model on Prussian soil. This should necessarily have appealed to Liebig, since it would have been equivalent to an intellectual-political triumph over the latter state, where Liebig had recently claimed there was not a single university offering practical training in chemistry.[18] Or did Liebig have an even more audacious plan in mind?

Exactly one month prior to Hofmann's introductory lecture in Bonn, Liebig set out on his fourth visit to England. Ever since the first wave of British students arrived in Giessen in 1836, Liebig had found himself irresistibly fascinated with this country.[19] Great Britain must have seemed a "land of unlimited opportunity" to a chemist. Liebig had even toyed with the idea of emigrating there in order to devote himself exclusively to his agrochemical experiments. The lightning visit in the spring of 1845 was intended as preparation for such a move. Under a seal of absolute secrecy, Liebig entrusted his friend Wöhler with the news that he wished this time to undertake "an enormous experiment" to verify his agrochemical ideas.[20] In fact, jointly with two British partners he had established a fertilizer factory in Liverpool.[21] Despite the fact that this firm was not blessed with great success, it is quite clear that an interest in practical applications was what Liebig was pursuing in England.

The date of the trip coincided with a decisive phase in British chemistry. After decades of stagnation the discipline had achieved a leading role in the modernization of science, in no small measure due to demands of the economy. Public recognition and professionalization in chemistry were much further advanced in England than on the continent; missing, however, was an appropriately modern educational facility. William Gregory, chemistry professor at Aberdeen and a former student of Liebig, had been stressing this point since 1842. Bullock and Gardner, also former Liebig students, made a public suggestion in 1844 that a private institution be founded, on the Giessen model, for education and research in chemistry.[22] The motives of these clever, business-oriented young men were an elevated status for the discipline and the promise of rich profits. They attracted support in a circle of wealthy landowners interested in improvements in agriculture and mining, as well as among physicians, druggists, and industrialists. The plan gained an important advocate in the person of the queen's physician, with whom Liebig also had close contacts. Before long a nucleus of subscribers had been assembled, and even the support of the crown had been won. Needless to say, only a student of Liebig could be considered for the role of director of such an institute. And so it was that Hofmann was offered the directorship of the Royal College of Chemistry in London. The proposal sounded not only speculative but even visionary.[23]

Fig. 1. A. W. Hofmann in his 28th year (1846), heliogravure from an (unknown) drawing, 116 × 91 mm, from Jacob Volhard and Emil Fischer, "August Wilhelm von Hofmann: Ein Lebensbild," *Ber. Dtsch. Chem. Ges.* **1902**, *35* (special issue), prior to p. 33.

The moment of decision came at a meeting in August 1845, when Queen Victoria and the Prince Consort were visiting Schloss Brühl as guests of the Prussian court. From there they made a trip to Bonn, where Prince Consort Albert was anxious to see once again the building in which he had lived as a student. In the meantime, who but Hofmann should have installed his laboratory in that very building! This favorable coincidence led to the confirmation of the appointment at the highest possible level, since both the Prussian ambassador and the Minister of Education were also in attendance. One formal obstacle—the fact that instructors were not employed members of the faculty, and thus not eligible for leaves of absence—was dealt with in an elegant fashion: the Minister of Education simply promoted Hofmann on the spot to the rank of assistant professor *(ausserordentlicher Professor)*, and then granted him a leave of absence. Hofmann was offered a laboratory with space for

40 students, assistants, and technicians, free lodging, and an annual income of £ 400 with a £ 2 supplement from the tuition of each student. After two years he was promised an annual raise of £ 100, up to a maximum stipend of £ 700—and in the interest of security, 600 talers [equivalent to £ 51] to permit him to return to Bonn. With ten times the income that a professor at Bonn could anticipate, Hofmann planned to return in two years as a successful man with 10000 talers in his pocket, suitably prepared for marriage. Full of self-confidence he wrote back to Giessen:

My dear professor, what will you say when you hear that in all probability I will be going to England. It may be that I overestimate my abilities, since recently all my investigations have been so crowned with splendid success, but I believe I am the man who can make something of the situation there. Once in a lifetime each of us is offered a very special chance, and the daring man seizes it. What marvelous opportunities to move forward in science and establish a reputation for oneself are not offered in England![24]

A Conspiracy

The outcome of this situation was hardly inopportune from Liebig's perspective. Or might it not be that he arranged the whole thing himself? At the very least it is noteworthy that Hofmann's contract became valid only after Liebig had approved the conditions. Having a reliable bridgehead in England was almost preferable to emigrating there himself. It would appear, however, that Liebig and Hofmann secretly pursued designs that none of their contemporaries could have imagined.[25] It may have been Hofmann's work on the bases in coal tar that gave Liebig the idea to investigate more closely the residues from cinchona bark and quinine production known as "quinoidine," which was discovered in 1822 to contain an amorphous mixture of alkaloids. Liebig discovered that this quinoidine could serve as a source for crystalline quinidine [a stereoisomer of quinine], with a composition identical to that of pure quinine itself and displaying equivalent therapeutical activity. This led to a scheme to buy up supplies of quinoidine from all over Europe, then patent the process, publish the analytical results, and finally sell the now valuable material at a good profit. Capital was of course required, but also important—from the standpoint of patent rights—were British comrades-in-arms. A consortium was therefore established in which Liebig, Hofmann, Bullock, and Gardner each held one-sixth shares. The chancellor of the University of Giessen, on the other hand, had two-sixths, since he represented the actual source of the funds. All but the latter belonged to the narrow circle around the founders of the Royal College of Chemistry. They must have felt rather like conspirators preparing to join in the new game of "capitalism." A sum of 50000 gulden had already been invested in the project when, through carelessness, the affair came out and the whole scheme collapsed.

The stereotype of Hofmann as one who ventured forth "from the spiritual heights of a German university ... inflamed" with "a pure passion for knowledge of the true and the beautiful, unsullied by the pursuit of material advantages,"[26] who arrived in a materialistic England and there capitulated against his will to the forces of industry—this stereotype is clearly due for revision. Indeed, it reveals all too openly the handwriting of its author, who was a master of stylization. In any event, Hofmann must have recognized in the quinidine affair a warning against future direct participation in business risks. He never succumbed to the "founders' fever" that later struck so many chemists. When his assistant William Perkin produced his first synthetic dye and—having just turned 18—wanted to try his luck in industry, Hofmann reacted "much annoyed, and spoke in a very discouraging manner ... Hofmann perhaps anticipated that the undertaking would be a failure, and was sorry to think that I should be so foolish as to leave my scientific work for such an object."[27] Nevertheless, to see Hofmann as the archetype of the pure scientist[28] would be a mistake. "Whatever you now do," he once advised Liebig (hardly an inexperienced bystander in such matters), "don't lift a finger unless there is financial compensation."[29]

Branching Off

Conceived originally as an educational institution, the Royal College of Chemistry was also a testing laboratory, which was supposed to provide its private financiers with certifications and analyses. Landowners and mine operators, apothecaries and druggists, industrialists and businessmen, all anticipated that their investments would be rewarded in productivity and the jingling of coins. But Hofmann was quite conscious of the dangers in an overly shortsighted, utilitarian operation. The fact that the Giessen model of research-oriented education had been transplanted into the more utilitarian climate of Britain meant that the character of the institution would necessarily change as well. London was not the place for the selfless pursuit of pure science. It was important instead to justify the research imperative as a pedagogic vehicle directed toward scientific results in the form of new laws and compounds that could in turn be applied in a beneficial way within industry and commerce. The gap between theory and practice, the tension between the demands of commerce and the ideals of scholarship—Hofmann dealt with these through a rhetoric that treated the utilitarian as a more or less inevitable spin-off from the scientific quest for knowledge.

Even though the curriculum of the College[30] offered a fixed three-year course of studies, what made it attractive was the fact that the extent and intensity of the required work could be tailored to the individual, who could enter the program at any stage. Fully half the students enrolled for only a single semester, often to conduct investigations important to their own particular professions. Others came to seek the qualifications necessary for carrying out research. Hofmann's ability to recognize talent and provide each applicant with an appropriate assignment from his rich storehouse of ideas was as famous as his knack for selecting outstanding associates. In this way the focus of the College shifted more and more in the direction of pure organic chemistry.

It is nearly impossible to describe all the projects undertaken by Hofmann and his students. As in any research program, detours, special opportunities, and outside commissions played a role, and one substance or another inevitably resisted the will of the chemist. Nevertheless, Hofmann succeeded in developing a characteristic research style in London. One of his earliest projects, executed in Giessen but presented before the Chemical Society in April 1845, was introduced with the remarkable assertion that a new direction had become apparent in organic chemical research. Whereas in the past one had always operated in a purely analytical mode, and rarely "with the goal of preparing particular compounds postulated through prior speculation," now the groundwork had been laid to conduct targeted "synthetic experiments" for the artificial preparation of organic compounds. "If a chemist were to succeed in transforming naphthalene in a simple way into quinine, we would quite properly honor him as a benefactor of humanity. Such a transformation has not yet been accomplished, but that alone does not imply that it is impossible."[31]

The concept of synthesis is a key to Hofmann's way of thinking. If the analytical phase of organic chemistry began with Liebig, in Wöhler's synthesis of urea Hofmann saw the threshold to the next higher step: an "era of synthetic chemistry."[32] A decisive shift in emphasis for the discipline had thus been recognized. This change is associated in no small measure with the name of another man who also traveled to London in the fall of 1845: Hermann Kolbe. With acetic acid, Kolbe succeeded in completing the first targeted synthesis of an indisputably organic compound starting from its elements.[33] In fact, the synthetic program of modern chemistry evolved in very important ways from the work undertaken by Kolbe and Frankland at the Royal School of Mines in the 1840s. The idea of "synthesis," for which popular accounts had predicted so much, reached its programmatic summit in the work of Berthelot. But as early as 1858 Kolbe had prophesied:

> *In the present state of our still-youthful discipline one may make the bold claim that as soon as the chemical constitution of substances such as indigo, alizarin, quinine ... has been correctly diagnosed, we will be in a position to assemble these materials artificially from their more intimate components.*[34]

It was left to Hofmann to transform this agenda into practice, and this he did with spectacular success. At the same time, however, for Hofmann the concept of synthesis held more than a mere chemical connotation: consistent with his creative, esthetic, nonanalytical way of looking at things, synthesis appeared to offer a vision of creativity in the face of the emerging machine age, and the prospect of wholeness as opposed to a science increasingly dominated by division of labor and a narrow-minded concentration on detail.

It is certainly characteristic that Hofmann's research program was eminently product-oriented. His positivistic, theory-abstaining stance corresponded to the spirit of the new age itself, the spirit of goods and the marketplace. Hofmann thought strictly in terms of *classes* of substances, which were to be investigated systematically and thoroughly once a pilot study had revealed some synthetic access. Analogy was his leading heuristic principle; his method was to systematically chart possible derivatives, toward which targeted syntheses were then directed. Hofmann operated strategically, in accordance with the expansionism of his time. Extension and diversification were key words for him. He described chemistry as a "magical tree, reaching out in every direction with its branches and twigs and infinite ramifications."[35] His central and often repeated metaphor of the tree comprises three crucial aspects: the nineteenth-century notion of evolution, the image of motion and vitality, and the many ramifications of Hofmann's own research program, at the heart of which was the researcher, supplying both guidance and planning. That, at any rate, is how his students saw it, and they extolled "the fertility of mind which, while he himself was conducting simultaneously several investigations, continually branching off into new ramifications, enabled him to suggest a multitude of fresh subjects for work to his students ... and to hold the guiding strings of all firmly within his grasp."[36]

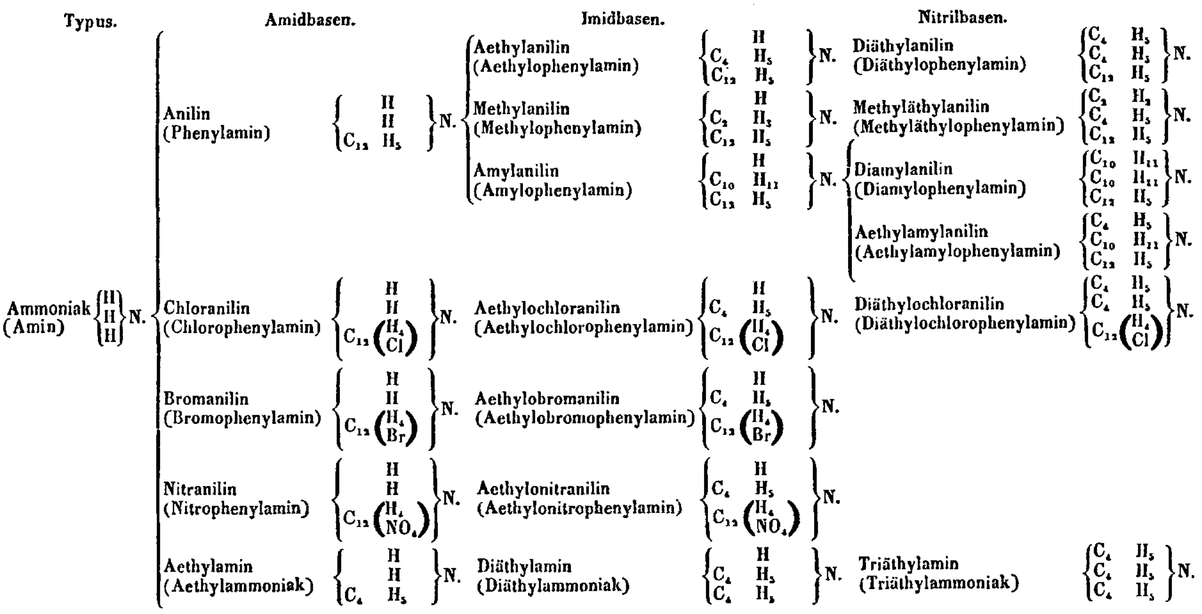
There is no need to explain to chemists that Hofmann could not have selected a better starting point for such an endeavor than aniline. This particular venture led to a series of ten "Contributions to an Understanding of the Volatile Organic Bases." The goal was to investigate the "remarkable analogy" between aniline and its derivatives, on the one hand, and ammonia, on the other.[37] Reactions with the halogens and alkyl halides were especially interesting. It became clear that the premise of the radical theory, according to which preformed ammonia must constitute one member of a "pair" in such compounds, was no longer tenable. In fact, the alkylated anilines could better be viewed as compounds in which the various hydrogen atoms of ammonia were successively replaced by organic residues. Application of the principle of homology permitted the number of possible combinations and their isomers to be increased almost without limit.

> *Here I find it impossible to avoid pointing out the wonderful versatility of isomeric compounds, to which a continuation of this investigation must necessarily lead. One sees at first glance that substances with the formula $C_{18}H_{13}N$ can be obtained by introduction of 1 equiv of methyl into xylidine, or 2 equiv of methyl into toluidine, or finally by attaching to aniline the radical (propyl) derived from the missing alcohol of propionic acid. We obtain in this way six alkaloids with the same formula, yet differing significantly in their constitution.*

$$\left.\begin{array}{ll}
\text{Cumidin} & \left\{\begin{array}{ll} & H \\ & H \\ C_{18} & H_{11}\end{array}\right\}N \\
\text{Methyloxylidin} & \left\{\begin{array}{ll} & H \\ C_2 & H_3 \\ C_{16} & H_9\end{array}\right\}N \\
\text{Aethylotoluidin} & \left\{\begin{array}{ll} & H \\ C_4 & H_5 \\ C_{14} & H_7\end{array}\right\}N \\
\text{Dimethylotoluidin} & \left\{\begin{array}{ll} C_2 & H_3 \\ C_2 & H_3 \\ C_{14} & H_7\end{array}\right\}N \\
\text{Propylanilin} & \left\{\begin{array}{ll} & H \\ C_6 & H_7 \\ C_{12} & H_5\end{array}\right\}N \\
\text{Methyläthylanilin} & \left\{\begin{array}{ll} C_2 & H_3 \\ C_4 & H_5 \\ C_{12} & H_5\end{array}\right\}N
\end{array}\right\} = C_{18}\,H_{13}\,N.$$

> *This number, of course, increases the higher we climb up the ladder of organic compounds. Two members are added at each rung, so that when we reach diamylaniline $C_{32}H_{27}N$ we*

are confronted with no less than twenty bases, the calling into existence of which will not be overlooked in the progress of science. —A striking example of simplicity in variety, which characterizes the creations of organic chemistry.[38]



The basic structure of ammonia permits one to obtain in this way a complete range of homologous substitution products, which Hofmann later designated as primary, secondary, and tertiary amines. Even though individual twigs were still unknown on this tree of possibilities that had unfolded itself in Hofmann's mind's eye, he remained confident that their existence "should be supportable by facts without difficulty;"[39] indeed, the synthesis of complicated natural products appeared to have moved into the realm of the possible.

The natural bases [quinine, morphine, etc.], may possess a more entangled composition. But a series of well-conceived experiments will not fail to cast light on the constitution of these compounds, and in this way place us in the position of constructing them in the same way it has been possible with the alcohol bases.[40]

Before Hofmann no one had ever conducted chemistry in this way. His approach represents an anticipation of basic strategies of industrial research, with the development and variation of entire spectra of products.[41] The program was to prove its worth a hundred times over in the broad field of organic nitrogen compounds. It is thus no wonder that Hofmann once compared his role as director of the institute with "the position of an industrialist in command of a splendid machine."[42] Instead of following Liebig's ingenious principle of basing research on an instrumental method, elemental analysis, Hofmann transformed the laboratory into a gigantic piece of machinery for the systematic synthesis of "chemical facts" in the form of new compounds and derivatives.

Types, Colors, Alliances

Substitution reactions had convinced Hofmann of the advantages of utilizing the notation of "types" for expressing chemical formulas. Substances with similar reactivities could thereby be assigned to a small number of basic types, in which atomic groupings were bound to one another in identical ways. Nevertheless, this was not meant to be an assertion regarding the true nature of either intramolecular groupings or bonding relationships; rather, the formulas were regarded simply as tools to aid in the classification of reactivity, and to assist in the search for analogies—a taxonomic model with no correlation with a reality that was assumed to be fundamentally unintelligible.[43] Compounds derived formally from a given inorganic primary substance all belonged to a single "chemical type." Hofmann seized upon this approach more firmly than his contemporaries as a guide to synthesis. He pictured it as a "type of construction" and a form of "template" in whose empty spaces atoms or atomic groups could be inserted like building blocks.[44] Hofmann's own model substance was of course ammonia.

Relative to all the other approaches to expressing chemical formulas, the type theory offered the tremendous advantage of permitting for the first time predictions regarding possible compounds of a given type. For this reason, type formulas were to provide the basis—along with the principles of analogy, homology, and variation—of the most important heuristic instrument and classification scheme in the new synthetic chemistry. Without his type theory, Hofmann's research program would have been impossible. He therefore remained true to the type notation even after it had been superseded by structural formulas. Entire series of publications on the volatile and nonvolatile organic bases [amines], the analogous phosphorus bases [phosphines] (17 papers, 1857–1860), and the "polyammonias" [polyamines] (24 papers, 1858–1863) testify to the effectiveness of the approach. Always pursuing several series of investigations simultaneously, and attacking across a broad front, Hofmann carried the art of serial publication to its first high point. He preferred to describe his method of operation as "analogic or template work."[45]

It was destined to prove its worth best in that field which to this day is still associated with Hofmann's name: coal-tar dyes. The corresponding history is too familiar to be repeated here in detail.[46] In 1856 Hofmann's assistant William Perkin oxidized aniline in the hope of obtaining quinine. The result was the first synthetic organic dye prepared in a research laboratory, aniline purple or mauve. This was followed two years later by Hofmann's discovery—and Verguin's independent discovery in Lyon—of fuchsin (magenta). The brilliance of these substances enchanted the ranks of high society, and they quickly acquired the status of "fashionable" colors. Industry and science instantly became conscious of the potential inherent in coal tar. Coal-tar dyes, together with their corresponding starting materials and intermediates, came to occupy the center of attention, leading in turn to a new relationship between chemical research and industry. The complexity of the substrate demanded the availability of professional chemists with both theoretical and analytical training, while translating results from the laboratory into industrial-scale ventures required the experience of industrialists. Virtually all the important subsequent innovations would come from the collaboration between these two worlds.

Hofmann himself first entered the new territory in 1860 in the context of his work on the polyamines.[47] The decisive factor was his contact with Edward Chambers Nicholson, whose company in London was one of the leading producers of chemical intermediates.[48] Studies related to aniline red (fuchsin), "chrysaniline," "rosaniline," and their derivatives, which we recognize today as triphenylmethane and acridine dyes, constituted thereafter the core of Hofmann's efforts. Systematically applying the principles of analogy and variation, he provided access to an enormous number of potential dyes and intermediates, at the same time clarifying their relationships to one another. Of outstanding significance was his discovery that the introduction of substituents into a dye molecule could lead to systematic changes in the dye's properties, facilitating the targeted development of specific nuances of color.

> *The facts elicited by the study of the action of iodide of ethyl upon rosaniline open a new field of research, which promises a harvest of results. The question very naturally suggests itself, whether the substitution for hydrogen in rosaniline of radicals other than methyl, ethyl, and amyl, may not possibly give rise to colours differing from blue; and whether chemistry may not ultimately teach us systematically to build up colouring molecules, the particular tint of which we may predict with the same certainty with which we at present anticipate the boiling-point and other physical properties of the compounds of our theoretical conceptions?*[49]

The chemical knowledge of the times, of course, set up certain barriers preventing the thorough classification and theoretical interpretation of the diversity of new dyes. This becomes especially apparent in Hofmann's case, since he remained firmly committed to thinking in terms of the ammonia type, which prevented him from ever understanding the true nature of the rosaniline dyes with respect to their triphenylmethane skeleton. Hofmann himself did not regard this as a particularly serious obstacle. Oriented in his thinking and in his work toward substances and away from theories, he saw it as precisely the point at which a purely scientific view must be supplemented by the pragmatic and problem-oriented approach of industry. "Though proud of her office as guide of industry, science acknowledges without blushing that there are territories on which she cannot advance without leaning on the strong arm of her powerful companion. Joint labours of this kind cannot fail to seal the pledge of alliance between industry and science."[50] Educated in a tradition that recognized a clear division of responsibilities and an even clearer intellectual priority of "pure" over "applied" chemistry,[51] Hofmann learned in England that the new era demanded new ways of thinking. In his report on the World's Fair of 1862, he concluded that industrial research constituted the highest and noblest activity, and should be accorded an equal status with pure science:

> *In the course of this review he [the reporter: Hofmann] has become more and more disposed to assign to the pursuit of industrial chemistry ... an equal rank with the very highest and noblest of the learned professions; and, in particular, to place it fully on a par with the pursuit of purely scientific investigations of any kind .... He desires to record it as his firm persuasion that pure and applied science will, hereafter, in an increasing degree, go hand in hand.*[52]

"To seal the pledge of alliance between industry and science"[53] was to become the equivalent of a magical formula for Hofmann.

In the Marketplace of Life

The London Great Exhibition[54] of 1851, a prestige project of the Prince Consort, marked a turning point in Hofmann's life. World's Fairs amounted to stages for the century itself, with commercial interests resplendent in a shimmer of glass and steel, light and national banners: masterpieces of consumption, shrines dedicated to the idolization of merchandise.[55] A vision of paradise on earth, offering glitter and luxury even to the masses—here it became truly palpable. Hofmann was active in the preparations for this first World's Fair, which was to set the pattern for those that followed. He was a member of both the German exhibition commission and the jury, and he edited the official report on "miscellaneous manufacture and small wares." The impetus to innovation emanating from the exhibition was of direct benefit to chemistry. A whole complex of new research establishments came into existence, and the Royal College of Chemistry was made a part of the School of Mines. As a result, Hofmann became director of a state institute of higher education as well as a British subject, and soon thereafter was named Assayer of the Royal Mint. Government agencies thought highly of him as a consultant, and he was an indispensable adviser to industry. In 1851 he was designated a Fellow of the Royal Society. The Chemical Society, of which he had been a member since 1845, elected him in 1847 to the post of foreign secretary, and then in 1861 to the presidency.

Fig. 2. A. W. Hofmann as professor at the London Government School of Mines, engraving by [John William] Cook, 16 × 11 cm from James Sheridan Muspratt, *Chemistry, Theoretical, Practical and Analytical as Applied and Relating to the Arts and Manufactures*, Mackkenzie, Glasgow/Edinburgh/London/New York, **1853**–**1861**.

Aristocratic landowners introduced Hofmann into the ranks of high society. The climax appears to have been an invitation to the estate of Lord Ashburton in the company of Thomas Carlyle.[56] Hofmann sparkled as an orator, delivering popular scientific lectures in front of the laboring classes in London as well as to the Crown Prince and Princess of Prussia at Windsor Castle—and finally even before the Queen and her children. As Hofmann himself perceived it, the interests of science were no longer subjects reserved exclusively for scientists; they had passed out of the laboratories to take their stand "in the market-place of life."[57] And in their company Hofmann himself became a recognized figure in public life: courted, honored, and influential.

At the apex of Hofmann's fame an opportunity arose to return to Germany. Bismarck's Prussia was on the point of backing up its political and military pretensions to leadership by modernizing institutions at home. Professorial chairs in chemistry had come available at two of the important centers of the land: those of Bischof in Bonn and Mitscherlich in Berlin. Chemistry at both institutions had fallen behind the level of development characterizing even the smaller universities, to say nothing of Munich and Leipzig, but Prussia was determined to set a new tone by issuing calls to prominent professorial candidates. Even the names Wöhler and Liebig were discussed. In 1863 Hofmann received an offer from Bonn, shortly thereafter one from Berlin.

Hofmann did not hesitate about returning to Prussia, which was beginning to take the lead in the modernization of Germany. His move was carefully prepared in advance.[58] Nevertheless, few at the time would have been able to appreciate his true motives. Friends advised him not to relinquish his prominent position in England. Liebig, who would perhaps have gladly received the offer himself (if only to be able to reject it), warned him against "transporting himself into the misery of German university conditions."[59] Actually, Hofmann probably foresaw that the traditional structures of British society, business, and education were soon to become a hindrance to further progress in industry and science,[60] and he was one of the first to draw the obvious conclusion. Caro, Böttinger, König, Leonhardt, Martius, Meister, and other industrialists who had sought their fortunes as chemists in Britain during the 1840s and 1850s followed his example.[61]

The Germany to which Hofmann returned had little in common with the quiet land of his youth. The country was awakening. Within a few decades it would experience a modernization unparalleled in history. Provincialism and customs barriers were falling, and railroads and factory chimneys were reshaping the agrarian landscape of the "belated nation,"[62] which was preparing itself under Prussia's leadership to surpass its rivals. The era of factories and machines was dawning: the era of Borsig, Krupp, and Siemens. A wave of new incorporations reached its culmination in the chemical industry in the 1860s. Europe watched spellbound by the incredible tempo with which a new industrial sector arose, one that was destined in a short time to dominate the world market.[63]

Palaces and Temples

Universities also derived their share of spoils from the economic upturn. The Humboldt formula of "seclusion and freedom," once purchased dearly with a renunciation of political and economic power, was displaced by a new self-assurance in science that relied on the scientists' power to actually reshape the world. Chemistry assumed the leading role in the modernization of the universities. A new generation of magnificently equipped institutes came into being.[64] Bonn and Berlin represented a prelude. While still in London, Hofmann was assigned the task of preparing a report on the building plans. He accepted this commission with obvious pleasure, since he was very well aware of the symbolic significance of such "palaces and temples"[65] dedicated to progress and the religion of science. They gave clear expression to the new claims of scientists to validity and prestige: the "splendid suite of apartments for the director" at the institute in Bonn with its "imposing entrance hall, illuminated by a glass cupola above, and the splendid ball-room, extending through two stories, and amply satisfying the social requirements of a chemical professor of the second half of the nineteenth century!"[66] The proposed institute in the Dorotheen- and Georgenstrasse in Berlin was impressive on the basis of its size alone.[67] A total of 954000 marks had been allotted to the construction, two and one-half times as much as for the institute in Bonn. New standards were to be set here for modernity, albeit hidden again behind the type of Renaissance facade so dear to the industrialists and upper middle-class. Their economic power no longer bore any relationship to their political standing, and this led them to hide their historical perplexity behind historicizing pretense.[68] Hofmann was especially concerned to include terra-cotta medallions of the great chemists between the window arches, as well as busts of Liebig, Wöhler, and Faraday in the foyer.[69]

On May 7th, 1865, Hofmann commenced his lectures in Berlin, establishing himself temporarily in Heinrich Rose's old laboratory. Three years later the new building was ready. It boasted three large work rooms for beginning and advanced students; spectroscopy and photometry rooms; clean-up, weighing, and titration areas; metallurgical and forensic laboratories; workshops; and a roomy, private laboratory for the director. Hofmann was now in a position to pursue a research program along the broadest possible front.[70] He supervised more than 150 doctoral dissertations in Berlin, and his co-workers must have handled an equal number. The unprecedented dimensions of the resulting intellectual productivity are attested to by 899 scientific publications "Aus dem Berliner Universitäts-Laboratorium," 150 of them from Hofmann himself. Applying the principles of analogy, homology, and variation to the targeted synthesis of derivatives and to the discovery of new classes of compounds, here he was able to develop his working style to perfection. At the center remained as always organic compounds containing nitrogen, together with dyes, especially the rosaniline and quinoline dyes, but also dyes derived from beechwood tar. Reactive starting materials and intermediates for synthetic purposes also became important. Aromatic diamines, benzidine, xylidine, and methylated aniline derivatives were among the key substrates. Using the analogy between alcohols and amines as a heuristic tool, Hofmann prepared the aliphatic amines from C_9 to C_1, for which purpose he devised a general technique of amide degradation involving bromine and base. Systematic studies were also conducted on the derivatives of guanidine, isonitriles, and aliphatic mustard oils. A synthesis of formaldehyde permitted Hofmann to prove the existence of this long-sought molecule.

Reigning Chemist-in-Chief[71]

The close connection between the university research program and practical application was apparent in constant efforts to supply the dye and fine-chemical industries with new classes of substances and derivatives. An intimate, virtually symbiotic relationship soon joined the laboratory in Berlin with the chemical industry through former students who had accepted industrial appointments. The central figure was Carl Alexander Martius, one of Hofmann's assistants in London. In Berlin Martius assumed leadership of the Aktiengesellschaft für Anilinfabrikation (AGFA), thereafter enjoying a virtual monopoly with respect to the discoveries in Hofmann's laboratory and the placement of his graduates.[72] Hofmann also maintained ties with the inorganic bulk-chemicals industry through Hugo Kunheim, and with the developing pharmaceutical industry through Ernst Schering. The "alliance between industry and science" of which Hofmann had once dreamed was now a reality, albeit in a form very much in keeping with the patriarchal structure of the Wilhelmian era. The result was a complex interplay of give and take, interests and powers, gains and concessions, which—due to problems with the relevant source materials—eludes even today the grasp of the historian. Only in limited areas, such as the role played by professors in the various World's Fairs,[73] has it so far been possible to analyze the relationships with greater clarity.

Hofmann remained a master of "synthesis" when it came to matters of influence and power, always willing to accept nominations for new offices. His work load was incredible.

> *When he was seized by a new challenge, bodily needs seemed for him no longer to exist. A long lunch break was a useless waste of time, and hours devoted to sleep were reduced to a minimum. Even younger associates found it difficult in those days to keep pace with Hofmann at work, and I venture to doubt whether the occasional invitations to his assistants at two or three in the morning to join him in a glass of punch in order then 'to finish the job just like that' were always received as an unmixed blessing.*[74]

Institute director and professor at the Friedrich-Wilhelms-Universität, as well as its rector (1880/1881), Royal Privy Councillor Hofmann was at the same time a professor in the Military Academy, full member of the Academy of Sciences, full member of the Scientific Delegations for Medical and Educational Affairs (from 1864) as well as the Delegation for Trade and Commerce (from 1864), member of the directorate of the Patent Rights Society (from 1873), member of the Imperial Patent Office (1877–1882), full member of the Imperial Office of Public Health (from 1880), chemical adviser to the Chancellor of the Reich, and an expert witness before the courts. When the Assembly of German Natural Scientists and Physicians *(Versammlung Deutscher Naturforscher und Ärzte)*, with all its rich tradition, survived a stormy controversy in 1890 that resulted in a new set of by-laws intended to enhance its professional standing, it was once again Hofmann who was entrusted with the delicate position of the presidency.

Nevertheless, it was the German Chemical Society *(Deutsche Chemische Gesellschaft)* that emerged as the true focal point for the diverse interests of chemical industry and chemical science.[75] The Society constituted an imaginary stage upon which Hofmann was to perform as the star in a production that seemed written just for him. Martius and Wichelhaus, his closest associates, took the initiative in founding the organization, but it is tempting to think that Hofmann himself was the source of the idea. He described its purpose as follows: "the new Society is actually designed to provide an opportunity for the mutual exchange of ideas between representatives of the speculative and applied branches of chemistry in order to seal anew the alliance between science and industry."[76] Founded on November 11th, 1867, in the Great Hall of the Institute of Trade, the Society elected August Wilhelm Hofmann to be its first president. He would occupy this chair fourteen times in the next twenty-five years. But even during the eleven years in which he was "only" vice-president, Hofmann held the reins of power in his own hands. "It is self-evident," he assured Wöhler when the latter was proposed for the presidency, "that your assumption of this office will not cause you the slightest worry, or trouble you in any way. We ask nothing more than the honor of seeing your name at the pinnacle of this Society."[77] Indeed, Wöhler's only obligation was that of adding his signature to documents presented to him by the secretary "in a cozy portfolio."[78] Hofmann appears to have directed the course of elections in other cases as well. Thus, when the election of Hermann Kopp was under consideration, Hofmann turned to Bernhard Tollens with the request that he "add the weight of your voice, along with those of your friends, colleagues, and students, to the scales" in the interest of his friend.[79]

Hofmann maintained his leading role in the German Chemical Society for a quarter of a century by exercising incomparable diplomatic adroitness, and by using this instrument he helped to determine the overall development of chemistry in Germany. Walter Ruske acknowledged as "a phenomenon difficult to understand for a contemporary observer" the degree to which the style and image of the Society was stamped in the image of a single man: "It almost appears as though Hofmann was literally forced into the role of a hero of German chemistry by his admirers, and the descriptions they provided of their master bear all the marks of a patriarchal model."[80] Hofmann knew how to make full and ceremonial use of all the authority that flowed in his direction. With eloquence and politeness, coupled with an almost youthful charm, he was an expert at transforming tension into a communal sense of self-assurance, preventing conflicts from ever developing, and finding common ground where there appeared to be a direct conflict of interests—a master at synthesis in this context as well.

Dissonance and Jubilation

The chemists tried very hard to convey an impression of self-confidence, both progressive and imperial, but in reality they felt a certain insecurity. Ever since the declaration of the Reich, worries and skepticism with regard to "progress" had merged with the fervor of the "founders' years" *(Gründerzeit)*. The belated and correspondingly accelerated modernization threatened to redraw the established boundaries of class and status. Modernization and industrialization also made their appearance within the universities. In no other discipline was the new role played by the natural sciences in the industrial era so apparent as in chemistry. Conflict with the traditional self-image of the universities was unavoidable. It peaked with a demand that chemistry and the other applied natural sciences be excluded from the universities altogether and banished to polytechnics or appropriate specialist institutions.[81] "The 'spirit of New York' now making its way into Berlin," wrote Heinrich von Treitschke in 1873 in reference to the University of Berlin, "threatens to endanger the life of the nation; it would be impossible to take action too strong in establishing an optimum counterbalance against the forces of consumption and pleasure," especially since some of the faculty already perceived themselves as part of a "university *en décadence*."[82] Anyone hesitant to retreat into the "ivory tower of academics" could escape the trials of the time only in aesthetic ventures with the vision of a more perfect, nobler world. Idealization and tendencies toward harmonization left their distinctive mark on the picture of the imperial Reich. What followed was an era of pomp and posturing, festivals and parades.

Hofmann was a genius at staging, at careful and exacting preparation, and the grand gesture. Even his lectures were recognized as histrionic masterpieces, "very dramatic, indeed theatrically honed."[83] For example, in order to demonstrate the bleaching effect of chlorine he once ordered an entire basket of violets and robbed them of their color, after which "with friendly jests and charming grace Hofmann threw the bouquets to his pupils."[84] But his *pièces de résistance* were the celebrations of the German Chemical Society. The new building for the Chemical Institute at the University had barely been completed when Hofmann invited the members to a "club night with the President." His intent was to make up for the spirit of elegance and consecration that had been absent when work first commenced in the "halls of the new temple": "None of those distinguished and eminently distinguished gentlemen in whose radiance we might on this occasion have shone, no bemedalled dignitaries of the Reich with their followers, no blossoming wreath of white-clad maidens to greet us on the steps of the sanctuary!"[85]

In 1870 after two years in office as president of the German Chemical Society, Hofmann passed the position on to Rammelsberg. In doing so he invited all the members, together with colleagues from the academy and the university, ministers, state officials, and diplomats, to a banquet that was to become a model for all their future ceremonial gatherings: a veritable firework of speeches, witty toasts, and congratulatory telegrams from all over the world. The purpose of the event was obvious: the effusive ovations served no other end than to portray Hofmann's return to Germany and the renunciation of his magnificent position in London to become a "simple German professor" as a rejection of the banal utilitarianism of the English, a yearning for the "higher, more ideal interpretation of things" found only in the German universities—remarkable testimony to the posturing and pretense of the founders' years. Hofmann edited the ceremonial report himself, and distributed it at his own expense as a special issue of the *Berichte der deutschen Chemischen Gesellschaft*.[86] Its title page portrayed Hofmann posing as an Olympian; in place of the goddess Victory he held in his right hand a bottle of aniline as he reigned sovereign over a multitude of profitable dye-putti bearing sacks bursting with talers. We must not let ourselves be disappointed by the antiquated Germanic frame and the clumsy lines of the artist: had any German professor ever before appeared in such an undisguised imperial attitude, or assumed so shamelessly the attributes of political and economic power?

This was not to pass without protest, and one of the greatest scandals in the intellectual history of the imperial Reich followed in its wake.[87] From Leipzig, a stronghold of middle-class mistrust of the upstart capital Berlin, Kolbe raged against the "arrogance of that Society, which calls itself 'German.'"[88] His colleague, the astrophysicist Zöllner, launched an unbridled attack against Hofmann and the modern scientific establishment in general. Hermann Cochius, one of the founding members of the German Chemical Society, resigned in protest against the dominant tone soon after the Hofmann celebration, distancing himself explicitly from the "clique of Berlin *raisonneurs*."[89] Friedrich Mohr wrote quite openly: "There prevails in the German Chemical Society in Berlin an attitude of toadyism and subservience that would make anyone nauseous.... I myself have fought for some time ... against the patented science of the current leaders."[90] Friedrich Rüdorff, chemistry professor at the Berlin Architectural Academy, feared nothing could be altered by criticism: "at the least they are likely to proceed with undiminished strength about the business of the great European society founded for the purpose of mutual and self-adulation (of which I myself am one of the oldest members)."[91]

Rüdorff turned out to be right. The success of the experiment in "modernity" was increasingly called into question, contradictions began to intrude into business and society as a result of the ebbs and flows of economic cycles and the so-called founders' crises, societies and special-interest groups were organized, complaints were voiced over depersonalization and declining quality, and disputes arose concerning academic versus vocational education, universities versus technical colleges, culture versus civilization. Yet, the more differentiated and dissonant this Wilhelmian Germany became, the more brilliant and jubilant were the festivities of the German Chemical Society: expressions of a deep desire to rise above the conflicts of the day, to compensate for dissonance in society with the harmony of a community.

Harmony and Luster

No excuse for celebration was wasted. A drinking party was held for 1500 students in Berlin's largest ballroom in 1878 in honor of Hofmann's 60th birthday, followed by a magnificent dinner for 200 guests. Hofmann arranged for participation by delegates from the four corners of the earth.[92] A convention was held in 1886 by the Assembly of German Natural Scientists and Physicians, at which Virchow and Hofmann were named managing directors. The German Chemical Society was responsible for organizing the chemical sections. A ceremonial reception was included, and the Society distributed to all in attendance a witty publication called the *Berichte der durstigen* ("thirsty") *Chemischen Gesellschaft*,[93] from the same publisher and in the same format as its staid journal, the *Berichte der deutschen Chemischen Gesellschaft*. The light-hearted tone and coarse jokes of this "journal" were in stark contrast to the otherwise solemn demeanor of the distinguished assembly of professors, directors, and industrialists. For Hofmann's 70th birthday the Society contributed a marble bust, together with the initial funds for a Hofmann Foundation. A student fête followed in imperial Germany's great ceremonial style.

Finally, a stunning culmination was arranged in the form of an elaborately coordinated double event for the year 1890: a "benzene festival" in the chambers of the City Hall and an "aniline festival" in the Hotel Kaiserhof. The Kaiser himself was invited, together with the "highest dignitaries of the Reich"—of course to no avail.[94] The former celebration was a tribute to the 25th anniversary of the formula for benzene, as well as to Kekulé, its inventor. The latter saluted Hofmann's return to Germany 25 years previously, and the impact that had on industrial development. The centerpiece at the first festival was the brilliant architect of a courageous idea who, in the words of Hofmann in his laudation, "never had a dye in his hands, and yet ... by proposing his theory of benzene may have given the coal-tar dye industry a greater impetus than all of us together, who have devoted years of our lives to the investigation of dyes."[95] Meanwhile, at the other celebration, tribute was paid to the man of action, one whose syntheses had provided industry with building blocks for the future, "who carried the light of science into the workshops of technology, ... who raised Technology to a status equivalent to that of its sister: Science," in the words of Heinrich Caro, representing the dye manufacturers.[96] The question of academic standing versus practical application, which had sounded as a leitmotiv throughout chemistry's history as an academic discipline, was thus provided with a dual answer: "pure" science scatters applications in its wake, even if unintentionally, but only industry blessed with an equal share of rights is in a position to make science productive. The coal-tar dyes, products of the most complex of all industrial syntheses up to that point, would have been unthinkable in the absence of an alliance between science and industry. But even more was at issue with these magical substances.

The founders' years of the chemical industry were not a time for treating men and materials with velvet gloves. Sulfuric acid, chlorine bleach, and sulfite pulping operations produced hazardous emissions at a level scarcely imaginable today. Exploitation reached its height, and plumes belching from the smokestacks of the factories were the pride of every entrepreneur. Coal tar was recognized as a particularly repulsive by-product, and it was produced in vast quantities during the gasification of coal. And yet it was precisely this scourge that was to become the starting point for a blossoming industry. It is certainly no coincidence that whenever the occasion arose to illustrate the utility of chemistry, Hofmann chose as his example not the mass-produced chemicals or the metals, not the dramatic improvements achieved in soda and mineral-acid manufacture, not the crucial fertilizer sector, not the introduction of wood-based cellulose as the basis of a new mass culture, but always dyes—a field that in the 11th edition of Rudolf Wagner's *Handbuch der chemischen Technologie* (Leipzig, 1880) warranted a scant 72 out of 1100 pages. It was not actual utility that was here thrust into the debate: many of the early dyes were primarily used in the treatment of silk, purely a luxury item. Much more at issue was fascination with the transformation of a detestable raw material into shining offspring steeped in elegance and luxury: "the way from coal to colour,"[97] a scientific fulfillment of the alchemist's ancient dream of transmutation.[98] It was this theatrical display that had occupied the center of public attention at the Internation Exhibition of 1862. Some of the glow is reflected in Hofmann's report:

In these cases is displayed a series of most attractive and beautiful objects, set in sharp contract with a substance particularly ugly and offensive. This latter is a black, sticky, fetid semifluid, equally repulsive to sight, smell, and touch: one of the most noisome, as it is also one of the most abundant and (heretofore) embarrassing, of the gas manufacturer's waste products. It is, in a word, gas tar.

The beautiful objects amidst wich [sic] the tar is placed are a series of silks, cashmeres, ostrich plumes, and the like, dyed in a diversity of novel colours allowed on all hands to be the most superb and brilliant that ever delighted the human eye. Language, indeed, fails adequately to describe the beauty of these splendid tints. Conspicuous among them are the crimsons of the most gorgeous intensity, purples of more than Tyrian magnificence, and blues ranging from light *azure to the deepest cobalt. Constrasted with these are the most delicate roseate hues, shading by imperceptible gradations to the softest tints of violet and mauve.*[99]

The aesthetic of shine and luster was as much a part of the image of Wilhelmian Germany as its inclination toward the decorative and colorful. The sober reality of power and material acquired a second and artificial skin, appearing to be ennobled to culture. It was a remarkable (but for the times typical) preference for the ceremonial over the commonplace that conferred such a high symbolic value on iridescence drawn from tar. Gottfried Semper had extolled the introduction of gas illumination for its enrichment of the festive,[100] and in a similar way the conspicuous rhetoric surrounding the coal-tar dyes constituted a part of the apparatus of idealization and ennoblement with which the aspiring profession of chemistry freighted its vision of the future: science could help transform the inhospitability of cities and their industries into a festival of bright colors. Critics have described the reign of Wilhelm II as an "age of festivals."[101] The monarch himself, with his peculiar inclination to the operatic, represented precisely what the public desired: pomp and glory. "Even the simplest of things was transformed in Bengalic illumination," observed Nicolaus Sombart.[102] The same words could almost have been used to characterize Hofmann's style in his later years.

Prestige and Effect

Through their unique mix of glorification of the free life of the student, of whimsical superabundance, of that drive to impress so characteristic of the founders' years, and of the general national pathos, the chemists' celebrations betrayed all too clearly how little this band of professionals had established its footing in the new role to which it had ascended on the strength of its academic and economic might. Status and acceptance were dominant social values of the time,[103] but in chemistry a wide gulf separated pretension from reality. Avoidance of things political after all constituted the core of that silent compromise into which intellect and capital had entered under the protective mantle of state authority. Neither party—scientists nor industrialists—had any serious part to play at the real center of power. The greatest height to which a scientist could hope to rise was to become a model for the educated middle class, the "Bildungsbürgertum," but chemistry rested on one of the lower rungs of the disciplinary ladder. Status in Prussia was measured on a prestige scale shaped by the aristocracy and the military. Professors were not even represented on the court's list of high-ranking individuals. This made all the more important the carefully crafted system of titles and honors with which the traditional elite attempted to ensnare members of the aspiring middle class. In the year 1888 Hofmann, too, was rewarded with a title of nobility by Kaiser Friedrich, whose brief reign was the subject of so many hopes.

The impression of a leading role for natural scientists in German society of the second half of the nineteenth century, conveyed so often by sources close to the scene, is simply a myth.[104] In Imperial Germany the truth lay elsewhere. Chemistry was never blessed with a du Bois-Reymond or a Helmholtz. Chemists rarely ventured beyond the bounds of their own discipline and its closely allied industry; even marriages were commonly arranged within this social group. The circle surrounding Hofmann was also curiously limited. Shortly after his arrival in Berlin he admittedly communicated to his brother what he perceived to be compensation for the shabbiness and pettiness with which he was otherwise confronted at every step: "In the circles in which I travel, an academic enjoys encounters with industry and high finance, with the highest officials of the state, officers of every rank, artists in every field;"[105] but in truth his association was essentially limited to industrialists, co-workers, and "special colleagues" from the natural-science branch of the philosophical faculty. Few prominent figures appeared even at the numerous celebrations held in Hofmann's honor, leaving aside those from closely related disciplines. It is therefore reasonable to suggest that the ostentatious celebrations were intended primarily to shape and enhance the self-image of a profession that was in fact still somewhat insecure with respect to its true significance in society.

Fig. 3. A. W. Hofmann, ca. 1871, photograph by Carl Günther, Berlin, 90 × 56 mm, Staatsbibliothek Preussischer Kulturbesitz, Berlin, Coll. Darmstaedter, G2 1858 (5), f. 162.

The impression made on the outside world was correspondingly weak. Hofmann seldom appeared as a public lecturer except among chemists. Only when his duties required it did he take a position in daily affairs. The speech he delivered upon assuming the position of Rector of the Friedrich-Wilhelms-Universität attracted wide attention, but what he actually had to say on that occasion regarding division of the Faculty of Philosophy into separate faculties of science and humanities came across as weak and conventional: a rearguard action in the attempt to maintain the advantages associated with university status. Hofmann never followed a true policy in science, let alone in politics. In 1880 when he opposed the recognition of an antisemitic student fraternity—but at the same time pressed for the dissolution of a student "Committee Opposed to Antisemitic Agitation"—he was acting merely in his role as rector, attempting to keep the university free of politics and party confrontation.[106] Hofmann had no head for politics. He accepted the notions of monarchy and dynasty as pivotal, and he displayed an almost childish veneration for Friedrich's empress, who as a princess in London had once eavesdropped on his chemistry lectures. One searches in vain among Hofmann's speeches and writings for the name of Bismarck. To characterize him as a liberal nationalist would be something of an overstatement. Indeed, the widely traveled Hofmann had been a British subject for twelve years, and he always refused to be a participant in the growing nationalism. As for the German Chemical Society, with its high percentage of foreign members, he governed it according to the age-old model of the transnational community of scholars, and in England this "denationalisation of chemical science" was praised as one of the Society's most lofty achievements.[107]

Monuments

The restless Reich attempted with the help of historical myths to obscure the impositions of modernity. An excessive cult of monuments was the result. The monument to Arminius (*Hermannsdenkmal*) in the Teutoberger Forest (1875) and the Niederwald monument near Rüdesheim (1883) set the national tone. In the following years monuments were erected everywhere. In a world of expanding markets, of proliferating cities and industrial landscapes, materials and materialism, greed and profits, in a world characterized by horizontal expansion, monuments offered an element of verticality and meaning, pointing upward toward the sublime and away from the crudely materialistic, toward a realm of culture in which all historical contradictions were resolved.[108] It was unthinkable that the chemists should be immune to this passion for monuments.[109] Hofmann's laboratory in Berlin was probably the first building of its type to incorporate in its facade a rich sculptural program honoring the traditions of European chemistry.[110] Hofmann attached great importance to the busts of Liebig, Wöhler, and Faraday displayed in the entrance hall. But it was important that the world outside take notice as well. April, 1873, marked the death of Liebig, and the German Chemical Society decided immediately that a monument should be dedicated to him. In that very year, though it was also to witness the first of the founders' crises and an economic depression, a collection for the purpose was initiated among the chemists, energetically pursued by Hofmann.[111] Meanwhile, the German population as a whole was engaged in a collection to build a great national monument. The two monuments were unveiled within a few weeks of each other in the summer of 1883: the Kaiser doing the honors for a victorious Germania atop the Niederwald, and Hofmann for the Liebig statue in Munich. A second monument was erected to Liebig in Giessen, in July of 1890, and two days later one to Wöhler in Göttingen. It goes without saying that Hofmann delivered both dedication addresses. The tradition he thereby initiated continued for many years: by 1911 the German Chemical Society had erected no less than 21 monuments throughout the Reich.

Perhaps no preceding era had ever felt a greater need for history. Historicized styles of every imaginable type literally blossomed. It is no coincidence that an independent historiography of the natural sciences developed at the same time. Hermann Kopp set the standards with his *Geschichte der Chemie* (*History of Chemistry*; 1843–1847), a work that Hofmann greatly respected. Other descriptions followed from the hands of Gerding (1867), Wurtz (1868), and Ladenburg (1869).[112] Whether motivated by fundamental principles of a historiographic concern for source criticism, or by those of a panegyric, all these works shared one common characteristic: they invested a young discipline devoid of a history of its own with a mantle of tradition and permanence. Spurred on by both expedience and inclination, Hofmann contrived to make history an integrating element within the German Chemical Society. His genre was necrology; his preferred source, correspondence. Beginning with a commemorative address for Thomas Graham in 1869, Hofmann created a colorful bouquet of life histories—no less than 51 in number—which now adorns the yellowing volumes of the *Berichte*. The finest were collected in 1888 as three sumptuous volumes of *Erinnerungen an vorausgegangene Freunde* (*Remembrances of Departed Friends*), where they were accompanied by selections from the correspondence between Liebig and Wöhler. Lively, and displaying a fine sense of cultural history, the portrayals by Hofmann are testaments to a culture of affirmation, projecting the contrasting world of a pre-industrial idyll in which at the end of the day's toil one might seek after-hours consolation. But they also preserve the vision of a science at the heart of which stood the individual researcher, with all his hopes and disappointments; a science in which the ideal was most important, and financial gain was irrelevant; the vision also of a community of scholars, far removed from nationalistic delusions and the arsenals of the present day.

Under the Protection of the Patriarchy

Hofmann's portrait gallery, indeed the world of the founders' years quite generally, must be envisioned as a male phenomenon. Women played at most a decorative role, as when a "blossoming wreath of white-clad maidens"[113] adorned the formal opening of an institute, or during a social evening "a rich garland of lovely ladies looked down into the colorfully animated room from the loges and balconies."[114] Even as the wives of professors, corporate directors, and privy councillors, women were absent from the chemists' circles. Prussia was a bastion of male chauvinism. Nowhere else was opposition to women students so powerful and so enduring. Initially tolerated only as auditors in 1895, women were first allowed to matriculate or acquire the doctorate in 1908.[115]

And yet there existed certain isolated niches under the protection of this patriarchy, although it required a patriarch with the stature of a Hofmann to employ a female private assistant for almost three years, subsequently going so far as to help her acquire a doctorate—all without the news ever leaking out in Berlin. This case is documented in confidential correspondence.[116] In the summer of 1874 Hofmann wrote a letter to Wöhler enjoining the latter to be of assistance to his "not only charming, but also thoroughly educated pupil, Fräulein Julie Lermontoff," whose knowledge far exceeded the norm and who had the singular ambition "to take home with her from Germany a doctorate." Fräulein Lermontoff wished to apply for this purpose to Göttingen. "With our severe regulations here we are unfortunately not in a position to introduce to the scene something so unheard of as a doctoral degree for a woman." Shortly thereafter Hofmann once again requested that special considerations be accorded her due to the unusual circumstances: "despite her considerable knowledge Fräulein Lermontoff is naturally very shy, and would consider herself fortunate if the chalice of an examination might pass her by."[117] In October 1874, 28-year-old Julie Lermontoff from St. Petersburg received her doctorate in chemistry at Göttingen with physics as a minor, albeit not without standing for the usual examination.[118] This was certainly the first doctorate in chemistry for a woman in Germany, indeed the first by many years.[119]

The End of an Epoch

If we may accept the word of his brother-in-law and longtime co-worker Ferdinand Tiemann, Hofmann's image evolved in a contrapuntal way:[120] from that of a fiery combatant in the battle for science in a Germany only beginning to awaken from its Philistine repose; to one serious and strict in respecting his obligations, out of a regard for public welfare, as the new Reich contemplated assuming a strong-man posture on the way to becoming a modern state. He ultimately came to represent the one constant factor in the chemical world: cheerful, benevolent, of sparkling humor, and always mindful of conciliation as the epoch reeled in a *fin-de-siècle* fever toward its demise.

In 1890 the whole atmosphere of Wilhelmian Germany was transformed. Ever since Bismarck's withdrawal, the Reich had perceived itself facing an uncertain future. The supremacy of the past gave way to a labile equilibrium. Industrialization, fragmentation of the middle class, and a developing labor movement produced dangerous cracks in the apparent solidarity of a patriarchal order. Rampant materialism, specialization, and "professionalism": these were the bywords of the cultural crisis of the decade. The instruments of the founders' years, the program of conservative reform, no longer struck a resonant chord; even the vision of industrialism as conveyed by the literature of the times became inverted and assumed a distinctly negative character.[121] The contrasting image of the creative genius, as conjured up for example by Julius Langbehn's *Rembrandt als Erzieher* (*Rembrandt as Educator*, 1890) began to attract enthusiastic throngs. A diffuse and ambiguous critique of modernity established itself.[122] The Reich of Bismarck had gambled away the opportunity for modern industrialized society to guide a new elite toward new forms of scientific-economic-political cooperation.

Such circumstances called for one more grand celebration by the chemists in an attempt to promote unity: in honor of the 25th anniversary of the German Chemical Society. Preparations were well underway when, on May 5th, 1892, Hofmann died, in the fullness of life and with a completed manuscript lying on his desk: it was to be the 887th contribution "Aus dem Berliner Universitäts-Laboratorium."[123] His funeral was worthy of a prince.

Hofmann's death marked the end of an epoch. The generation of the founders had retired from the scene. Siemens, who had coined the phrase "scientific era," died six months later. A new generation of academic mandarins,[124] the privy councillors and grandiose professors, rejected exaggerated display and monumentality. Emil Fischer, Fritz Haber, and Walther Nernst, leading reformers and protagonists of a new style, distanced themselves through coolness, matter-of-factness, and precision from the exuberance of their predecessors. Their own plans for the future were based on complexity and competitiveness, not on hierarchies and a sense of community.[125] They no longer felt able to plaster over the rents and tensions plaguing the scientific establishment. In conflicts about state examinations, rights of the technical institutes, questions related to untenured faculty and instructors or the integration of research and teaching—everywhere the tones became harsher and more strident.

Is it any wonder that the times held fast to their image of Hofmann? That they in fact inflated it until it acquired monumental proportions, because modern scientists—and industrialists—were threatened with disappearance as individuals due to a new division of labor in the workplace? That they drew comfort from Hofmann's enormous vitality, because their era seemed powerless, hectic, and a primary cause of its own illness? That they rejoiced in the memory of Hofmann's unpretentious humor and winning charm, because times were now bad and the mood had become strident? That they swore by his ability to integrate and to synthesize, because industrial society had lost that unanimity and clarity that had characterized traditional society? "In times of almost feverish growth in activity in science and industry," began Tiemann in his obituary address before the German Chemical Society, "it is appropriate for us to look back more often than in the past in order not to lose sight of the broader perspective."[126] A biography that the Society commissioned Tiemann to prepare was not completed until 1902, and then by Volhard and Fischer. It finally appeared in the form of an impressive special issue of the *Berichte*: a testament of the preceding century, laid at the threshold of a new age.

Hofmann would be remembered once again. In April 1918, the German Chemical Society gathered to celebrate its own 50th anniversary and the 100th birthday of its founder.[127] Few were present because of the war, and indeed only a single foreigner. The atmosphere was one of dejection; achievements from the past were urgently recalled to counter the uncertainty of the future. Cabinet ministers and representatives of government agencies, the rectors of the university and the Technische Hochschule, presidents of the professional associations and of the Kaiser Wilhelm Society—all were duly in attendance, and tributes to the contributions of chemistry recorded "in the golden book of this war" were just as obligatory as telegrams praising Ludendorff and the "heroic" Kaiser. Only one of the seated dignitaries apparently maintained his silence through all the speeches and toasts: Fritz Haber, who came to represent the minister of war.

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Speaking out of the feverish restlessness of the *fin de siècle*, from the deep strife characterizing the turn of the century, and from the trauma of war, the German Chemical Society and chemists individually swore their allegiance repeatedly to the image of Hofmann. And it is this image that tradition has handed down to us. The accomplishments of this remarkable man were phenomenal for the time. In the stormy phase of economic rebirth and through the crises of the founder's years he was the central integrating figure, the figurehead. Hofmann's powers of synthesis were enviable. But must we therefore be envious of an era that stood in desperate need of such men?

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[1] Based on the classic portrayals by Jacob Volhard and Emil Fischer, "August Wilhelm von Hofmann: Ein Lebensbild", *Ber. Dtsch. Chem. Ges.* **1902**, *35* (special issue); L. Playfair, "Hofmann Memorial Lecture" in *Memorial Lectures delivered before the Chemical Society, 1893-1900*, Gurney & Jackson, London, **1901**, pp. 575-596; W. H. Perkin, "The origin of the coal-tar industry, and the contributions by Hofmann and his pupils," *ibid.*, pp. 596-637; Henry E. Armstrong, "Notes on Hofmann's scientific work," *ibid.*, pp. 637-732; F. Tiemann, "Gedächtnisrede auf A. W. Hofmann," *Ber. Dtsch. Chem. Ges.* **1892**, *25*, 3377-3398; B. Lepsius, "Festschrift zur Feier des 50jährigen Bestehens der Deutschen Chemischen Gesellschaft und des 100. Geburtstages ihres Begründers August Wilhelm von Hofmann", *Ber. Dtsch. Chem. Ges.* **1918**, *51* (special issue). More recent sources: Monika Müller, *Die Lehrtätigkeit des Chemikers A. W. von Hofmann in Zusammenhang mit seinen Leistungen als Forscher und Wissenschaftsorganisator*, Ph.D. Dissertation A, Humboldt Universität, Berlin, **1978**; "Aus dem Leben und Wirken des Chemikers und Hochschullehrers August Wilhelm von Hofmann (1818-1892)", *Beiträge zur Geschichte der Humboldt-Universität zu Berlin*, **1981**, *4*; Johann Mulzer, "Bedeutende Chemiker der Berliner Universität: August Wilhelm Hofmann und Emil Fischer" in *Berlinische Lebensbilder, Vol. 1: Naturwissenschaftler* (Eds.: Wilhelm Treue, Gerhard Hildebrandt), Einzelveröffentlichung der Historischen Komission zu Berlin, Vol. 60, Stapp, Berlin, **1987**, pp. 27-44; Michael Engel, Brita Engel, *Chemie und Chemiker in Berlin: Die Ära August Wilhelm von Hofmann, 1865-1892*, Studien und Quellen zur Geschichte der Chemie, Vol. 1, Verlag f. Wiss.- und Regionalgeschichte, Berlin, **1992**. A reliable personal bibliography does not exist. Sources are given in the present contribution only for literal quotations; additional information was derived from the literature assembled here.
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[3] W. Will, *Zum Gedächtnis an A. W. von Hofmann, Rede auf der Trauerfeier der Universität am 22. Juni 1892*, Friedländer, Berlin, **1892**, pp. 4-5; cf. *idem.*, "Festrede bei der Enthüllung des Denkmals für A. W. von Hofmann in Giessen am 8. Juli 1918," *Ber. Dtsch. Chem. Ges.* **1918**, *51*, 1693-1704, here p. 1695.
[4] Hofmann, autobiography (cf. note 2), folio 1v.
[5] Liebig to Wöhler (12 July 1840), Bayerische Staatsbibliothek München, Liebigiana II A 1 (Wöhler), No. 180.
[6] Frederic L. Holmes, "The complementarity of teaching and research in Liebig's laboratory," *Osiris* **1989**, *5*, 121-164.
[7] A. W. Hofmann, "Chemische Untersuchung der organischen Basen im Steinkohlen-Theeroel," *Ann. Chem. Pharm.* **1843**, *47*, 37-87.
[8] Compound names appear here in their original form. Where it would be useful for comprehension, modern designations have been appended in brackets.
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[10] Justus Liebig, "Über das Studium der Naturwissenschaften und über den Zustand der Chemie in Preussen [1840]", in Justus von Liebig, *Reden und Abhandlungen*, Winter, Leipzig, **1874**, pp. 7-36, here p. 12.
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[13] A. W. Hofmann, *Preface*, in Friedrich Wöhler, *Handbook of Inorganic Analysis* (Ed.: A. W. Hofmann), Walton & Maberly, London, **1854**, p. vii.
[14] Charles Dickens, *Hard Times* [1854], (Eds.: George Ford und Sylvère Monod), Norton Critical Editions, Norton, New York, **1966**, p. 1.
[15] Armstrong (**1901**), p. 725.
[16] A. W. Hofmann, *Einleitung in die moderne Chemie*, 5th ed., Vieweg, Braunschweig, **1871**, p. 222.
[17] Liebig to Mohr (9 November 1844), in *Justus Liebig und Friedrich Mohr in ihren Briefen von 1834-1870* (Ed.: G. W. A. Kahlbaum), *Monographien aus der Geschichte der Chemie*, Vol. 8, Barth, Leipzig, **1904**, pp. 82-83.
[18] Liebig (**1874**), p. 32.
[19] Eric Gray Forbes, "Liebig in Grossbritannien", *Nachrichtenblatt der Deutschen Gesellschaft für Geschichte der Medizin, Naturwissenschaft und Technik* **1983**, *33/3*, 115-133.
[20] Liebig to Wöhler (28 March 1845), in *Aus Justus Liebig's und Friedrich Wöhler's Briefwechsel in den Jahren 1829-1873, Vol. I*, (Ed.: A. W. Hofmann), Vieweg, Braunschweig, **1888**, p. 256.
[21] Liebig to Wöhler (26 April 1845), Bayerische Staatsbibliothek München, Liebigiana II A I (Wöhler), No. 279.
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[25] Brock (**1984**), pp. 14-17.
[26] "Bericht über das Festmahl der Deutschen Chemischen Gesellschaft zu Ehren A. W. Hofmanns" (Eds.: C. A. Martius, H. Wichelhaus), *Ber. Dtsch. Chem. Ges.* **1870**, *3*, supplement; cited in Lepsius (**1918**), p. 6.
[27] Perkin (**1901**), p . 605.
[28] Anthony S. Travis, "Science's powerful companion: A. W. Hofmann's investigation of aniline red and its derivatives", *The British Journal for the History of Science* **1992**, *25*, 27-44; here p. 27; cf. also Peter Borscheid, *Naturwissenschaft, Staat und Industrie in Baden (1848-1914)*, Industrielle Welt, Vol. 17, Klett-Cotta, Stuttgart, **1976**, pp. 114-115.
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[30] Cf. the contribution by G. K. Roberts in *Die Allianz von Wissenschaft und Industrie: August Wilhelm Hofmann (1818-1892)—Zeit, Werk, Wirkung* (Eds.: C. Meinel, H. Scholz), VCH, Weinheim, **1992**.
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[40] *Ibid.*, p. 175. In the terminology of the times, "alcohol bases" are *N*-alkylated compounds derived from ammonia by the introduction of "alcohol radicals".
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[56] Volhard/Fischer (**1902**), pp. 50–59.
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[107] Armstrong (**1901**), 729.
[108] Glaser (**1984**), p. 226.
[109] Ruske (**1967**), 54–60.
[110] These are larger-than-life terra-cotta medallions of Lavoisier, Scheele, Cavendish, Priestley, Dalton, Berthollet, Gay-Lussac, Davy, Berzelius, Mitscherlich, Klaproth, Rose, Gmelin, Gerhardt, and Laurent. Interestingly, there is none for G. E. Stahl, whose priority in the establishment of modern chemistry had been proclaimed polemically by German nationalists since 1870 (although his name was included among the finalists). Cf. Hofmann (**1866**), p. 71.
[111] Minutes of the Chemical Society, Staatsbibliothek Berlin, Sammlung Darmstädter, Sig. G2 1858 (5), Folios 15–26.
[112] Jost Weyer, *Chemiegeschichtsschreibung von Wiegleb (1790) bis Partington (1970): Eine Untersuchung über ihre Methoden, Prinzipien und Ziele*, Arbor scientiarum, Series A, Vol. 3, Gerstenberg, Hildesheim, **1974**.
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[114] Lepsius (**1918**), p. 29, Students' party for Hofmann's 60th birthday.
[115] Regine Zott, "Zu den Anfängen des Frauenstudiums an der Berliner

Universität," in *Perspektiven interkultureller Wechselwirkung für den wissenschaftlichen Fortschritt,* ITW-Kolloquien, 48, Akademie, Berlin, **1985**, pp. 29–37.
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[117] Hofmann to Wöhler (Berlin, 28 July 1874), *ibid.*, No. 24.
[118] Information gratefully received from Günther Beer and the Archive of the Universität Göttingen.
[119] It was a quarter of a century later before Clara Immerwahr, the first wife of Fritz Haber, earned her doctorate in chemistry at Breslau.
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