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MELVILLE LAWRENCE WOLFROM

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A Biographical Memoir by

DEREK HORTON AND W. Z. HASSID

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MELVILLE WOLFROM was born in Bellevue, Ohio, on April 2, 1900. He was the youngest of nine children in the family of Frederick Wolfrom and Maria Louisa (Sutter) Wolfrom. Originally, Melville's father's name was Friedrich Wolfrum, but some time before his marriage he anglicized it to Frederick Wolfrom. Melville's grandfather, Johann Lorenz Wolfrum, brought his family to America from the Sudeten German border town of Asch (now in Czechoslovakia) in 1854 and settled in a log cabin near Weaver's Corners, Sherman Township, Huron County, Ohio.

Friedrich Wolfrum attended the county schools and worked from an early age to help support the family. For many years he was in the dry goods business in a store in nearby Bellevue, Ohio, and later worked as secretary–treasurer of a local telephone company that was the forerunner of the Ohio Northern Telephone Company. He died when Melville was only seven years old; as a result, from an early age Melville was instilled with the need for self-reliance. When still quite young, he worked on odd jobs, especially during the summers. His mother had a great respect for cultural pursuits, such as music and good literature, and stimulated in him an interest in serious reading. Melville was brought up in a very strict orthodox Lutheran tradition; and, although in later years he did not adhere to this strict religious background, he consistently advocated some type of formal religious training for his children during their formative years.

During his early teens, Melville became involved in a small manufacturing business maintained in the family home. His three oldest brothers bought the patent on a type of horse harness snap that was used successfully by several fire departments. After school each day, on Saturdays and holidays, and throughout the summer vacations, Melville worked on the production of these harness snaps and was paid ten to fifteen cents an hour for his labor. During this time, he often tried to improve the devices and, as a result of this experience, determined to become a college graduate engineer with a view to a career in manufacturing.

Melville attended Bellevue High School and graduated second in the class of 1917. Stimulating teachers helped him develop an early interest in nature study, fine arts, mathematics, and German. His first encounter with science was in high school, where he learned physical geography and botany from a Mr. S. A. Kurtz. Later, he was much influenced by Mr. W. A. Hammond, with whom he studied chemistry and, later, physics. Hammond's influence was primarily responsible for Melville's decision to become a chemist, or, more specifically, a chemical engineer; the more "practical" aspect of the latter field was appealing as a result of his earlier experience in the workshop.

Being without family financial support, Melville was unable to enter college upon graduation from high school. Instead, he obtained a position with the National Carbon Company, a firm manufacturing wet and dry batteries in the nearby town of Fremont. There, in the works laboratory, he tested the quality of the daily products. Within six months he was placed, at the age of seventeen, in charge of the laboratory, with about six persons under him. Here he conducted his first research project, an evaluation of the physical properties of carbon dry-cell electrodes as a function of the conditions used in baking the electrodes. During the winter, he took an evening course in qualitative inorganic analysis, given at the plant. Early the following summer, he resigned his post to go to Cleveland, with the idea of entering Western Reserve University in the autumn and earning his board by waiting on tables. He worked during the summer at a boarding house and also at a variety of jobs in factories and laboratories in Cleveland that were busy at that time with war production. That autumn, the government established the Students' Army Training Corps, and Melville entered the naval unit at Western Reserve. The prescribed course of study included physics, but no chemistry. The courses were uninspiring, much disorganization resulted from the influenza epidemic, and he disliked the barracks life and the snobbish fraternity system of the school. When the armistice came in November 1918, he returned home to Bellevue feeling frustrated.

After working for a brief period as an advertising representative for a trade paper, in the autumn of 1919 he entered Washington Square College of New York University. The college unit was new and was not functioning well; no chemistry was offered. Again, he gave up his studies and returned to Bellevue, where he felt regarded as a disgrace and misfit.

The following year he worked at odd jobs, as a laborer and then as a bookkeeper. Finally, in the autumn of 1920 he entered The Ohio State University in Columbus and embarked on a course in chemical engineering, an endeavor that at last held his attention and interest and that he enjoyed greatly. For his board, he worked at boarding houses, restaurants, and cafeterias—as waiter, counter man, and dishwasher; he preferred the last kind of work. In general, he always preferred working with material things rather than with people; this preference was evident throughout his life, although he had an unexpectedly perceptive insight into the character of those people he got to know.

Young Wolfrom's first encounter with the chemistry of carbohydrates came at the end of his sophomore year, when Professor C. W. Foulk recommended him for a post as student research assistant to Professor William Lloyd Evans of the Department of Chemistry. The stipend was $250 per year, and Wolfrom put in all of his extra time on the work. During his junior year, he carried out quantitative oxidations of maltose with permanganate at various temperatures and concentrations of alkali. In his senior year, he attempted unsuccessfully to synthesize amino acid esters of glycerol. None of this work was published, but it was a good introduction to chemical research. Professor Evans, a student of J. U. Nef's, was very research-minded and inspirational. Wolfrom continued his work with Professor Evans and received the A.B. degree *(cum laude)* in 1924. The influence of Professor Evans and the other inspirational teachers of his undergraduate days was to endure throughout his career; the broad interdisciplinary approach that he took to research and the insistence upon careful observation, clear expression, and historical accuracy can all be traced to the early roots of his undergraduate training.

During every summer of his college career, Wolfrom worked at Gypsum, Ohio, with his high school chemistry teacher, W. A. Hammond, who was plant chemist for that installation of the United States Gypsum Company. Melville's well-to-do uncle, Frank A. Knapp, impressed by his nephew's progress, offered to loan him the funds to complete his college work, but Melville's mother sternly forbade him to take advantage of this offer, as it did not fit into her scheme of Spartan training for him.

Following graduation from The Ohio State University, Wolfrom moved to Northwestern University, in Evanston, Illinois, to carry out his graduate work under Professor W. Lee Lewis, a student of Nef's. He began research immediately and worked on it night and day, completing the M.Sc. degree in 1925 and the Ph.D. in 1927. His problem was to provide experimental evidence for the enediol theory advanced by Wohl and Neuberg to explain the Lobry de Bruyn–Alberda van Ekenstein interconversion of sugars in alkaline media. He observed that 2,3,4,6-tetra-*O*-methyl-D-glucose could be equilibrated with the D-*manno* epimer in aqueous alkali and that there was no loss of the 2-*O*-methyl group and no formation of keto sugars. The result pointed to an enediol intermediate common to the two methylated sugars and showed that the mechanism of enol formation was not one of selective hydration and dehydration, as had been suggested by Nef, but rather was consistent with a simple keto–enol tautomerism. This work, published with Lewis in 1928, was the first in what was to become Wolfrom's remarkably prolific output of research papers on the sugars, extending over more than four decades and numbering more than five hundred individual reports. He had a phenomenal memory for detail from his early work; forty years after his paper with Lewis was published, he could still describe it in exact detail without preparation, even to remembering the values of some of the physical constants.

While at Northwestern, Wolfrom held an unusual teaching post provided by the fire insurance underwriters' association that sponsored a technical course to selected scholarship holders at the University. The program included a course in chemistry, and Wolfrom taught this course in the laboratories of the nearby College of Dentistry, holding the rank of assistant instructor.

Wolfrom was married to Agnes Louise Thompson, of Auburn, Indiana, in 1926. She had been trained at Depauw University in Greencastle, Indiana, as a public school music teacher and later did advanced work at Northwestern University, where she met her future husband. Throughout their married life, she continued to be involved in music teaching and in musical activities in the community and was ever a sympathetic and stimulating helpmate to her husband.

After receiving his Ph.D. degree from Northwestern, Wolfrom was awarded a National Research Council Fellowship that enabled him to undertake a period of postdoctoral study with some of the leading investigators in his field of interest. First, he went to study with Claude S. Hudson, then at the National Bureau of Standards, in Washington, D.C., and the undisputed leader on the American scene in research on carbohydrates. Hudson, a student of Van't Hoff's, had a strong background in physical chemistry; and his individualistic philosophy of research impressed Wolfrom greatly: his continuity of purpose, his exacting standards in experimental work, and his conservatism in theorizing until a thorough basis of facts had been recorded. All of these attributes, together with Hudson's concise and lucid style of writing, were to serve as models to Wolfrom throughout his career. It is doubtful that two such strong personalities could have long coexisted in the same institution, but Wolfrom ever after regarded Hudson as an inspiring teacher and colleague, to whom he owed a great deal. Years later, they were to be closely associated in editorial and nomenclatural work, and they much enjoyed each other's company.

After a few months in Washington, Wolfrom moved in September 1927 to New York City in order to work in the laboratory of P. A. Levene at the Rockefeller Institute for Medical Research. Levene, the outstanding master on the North American continent in the young discipline of biochemistry, was an ardent genius with a remarkable capacity for hard work and an urbane and cosmopolitan personality; he had a warm interest in all of those who worked with him. In his contact with Levene, Wolfrom was able to assimilate at first hand some of the valuable aspects of the European traditions in science that Levene was able to convey to his co-workers at the Rockefeller Institute, and he was simultaneously exposed to the enormous challenge to the structural chemist offered by the seemingly hopeless slimes and mucins that were components of animal tissues. Levene had realized that more needed to be known about the structures of the simple sugars, especially the linkage positions in the disaccharides and the ring size in cyclic monosaccharide derivatives, before he could ever hope to achieve his goal of structural elucidation in the nucleic acids. Wolfrom worked with him on these aspects, and, within a few months, a paper resulted on the Wohl degradation of cellobiose and its use in determining interglycosidic linkage-position. In quick succession thereafter were published two more papers on the ring structures of methyl D-lyxosides. In the summer of 1928 Wolfrom returned to The Ohio State University to finish up his two-year fellowship. There he worked independently on the synthesis of stable derivatives of the acyclic forms of the sugars, as such acyclic intermediates had been so often proposed as transient species in reactions of the sugars. By removing the thioacetal groups from the pentaacetate of D-glucose diethyl dithioacetal, he was able to obtain and characterize the acetate of the free aldehyde form of D-glucose; similar work in the D-galactose series followed later.

In the autumn of 1929, Wolfrom was appointed Instructor in Chemistry at The Ohio State University and one year later was raised to the rank of Assistant Professor. He remained on the faculty of the Department of Chemistry at Ohio State for the whole of his career, becoming Associate Professor in 1936 and Professor in 1940. In 1939 he was awarded a fellowship by the John Simon Guggenheim Memorial Foundation; and, in February of that year, he traveled to Switzerland to work in the laboratory of Professor P. Karrer of the University of Zürich but returned to the United States at the outbreak of hostilities in Western Europe.

With the aid of the successive generations of students who came to carry out their graduate research under his direction, Professor Wolfrom was able to launch a wide-ranging program of research, with problems of structure and reactivity in the carbohydrate field constituting the principal theme. The procedures used for obtaining acetylated *aldehydo*-D-glucose were systematically extended through the sugar series, and new types of aldose derivatives containing substituents on the hydrated carbonyl group were obtained; these showed the predictable behavior in being isolable in two isomeric forms, epimeric at C-1. The new well-established fact that acyclic structures can exist as reactive sugar-intermediates, sometimes having considerable stability, rests largely on his pioneering work. His first Ph.D. student, Alva Thompson, showed that the acetylated oxime of D-glucose undergoes conversion from a cyclic to an acyclic form during the Wohl degradation, and for this work Thompson received the Ph.D. degree in 1931.

Professor Wolfrom often appeared rather formidable and awesome to the new graduate student, even though he was physically only of medium height and build. He expected of his colleagues the standards of work that he set for himself. It was often difficult for lesser people to live up to his standards. His own experimental research was always done with precision, and he was proud to show that the samples he had prepared himself in the thirties were undecomposed several decades later and that their purity was unimpeachable, even by the chromatographic techniques later developed. He expected that all melting points and optical rotations recorded by his students should be as authoritative as his own experimental values.

Not every student or colleague who came into contact with Wolfrom could accept his uncompromising standards. Professor

Wolfrom chose to expend his energies in those areas where the problems could be clearly defined; and, once he had decided what was the right course, he held steadfast to that position, regardless of outside pressures. He tended to avoid becoming involved in situations where negotiations and compromises had to be made, or where the issues could not be stated in precise terms.

A hard taskmaster, Wolfrom earned the greater respect of many of his students after they had completed their work with him. Despite his rather retiring and diffident manner toward groups of people not known to him, and despite the apparent gruffness and terseness that so often characterized his day-to-day contacts with his co-workers, he actually took a deep interest in the welfare of every colleague and student who had a genuine interest in, and aptitude for, science. He went to considerable lengths to help each of his students become established in a suitable post after graduation and kept in touch with a surprisingly large proportion of them long after their departure. He had a deep insight into human personality and found it intriguing to delve into the background and motivations of each of the persons with whom he worked. This interest is reflected in the number of biographical memoirs that he chose to write, especially of his early mentors; these were done with characteristic thoroughness and show his perceptive qualities in understanding human nature.

Although he never regarded lightly any of the work he undertook, Wolfrom had a very strong sense of humor, not always recognized by those who did not know him well. He had an endless store of anecdotes concerning the personalities of science, based on his own contacts with other scientists and on his wide reading of the history of science; the humor of his dry remarks would once in a while be betrayed by a fleeting smile. This side of his personality was most in evidence when he was with small groups of people he knew well and with small classes of advanced students who were perceptive enough to appreciate the subtleties of his comments.

His approach to teaching was always based on a solid, historical foundation that traced the development of science through the major milestones of factual knowledge, rather than through rationalizations and correlations that involved extrapolation of existing information.

At the graduate level, where he supervised almost a hundred Ph.D. students and numerous M.S. candidates, Professor Wolfrom made his major educational contribution. With these students he was able to pursue research on several broad fronts in the field of the carbohydrates. (A list of Wolfrom's published articles and the participating co-workers is given at the end of this memoir.) In the early days, most of the research students were employed as part-time teaching assistants in chemistry at Ohio State. Later, and especially after World War II, outside funding through grants and contracts from government and industry became available, and Wolfrom was able to expand his research program further. The research group was enriched by a regular succession of postdoctoral associates who came from other institutions for one or two years of experience in Professor Wolfrom's laboratory. The group became very cosmopolitan, always containing members from Europe and Asia, and Wolfrom particularly appreciated the new ideas and techniques brought in by these colleagues who had received their doctoral training in other laboratories.

Throughout his career, Wolfrom's early theme of research on the acyclic forms of the sugars continued; in fact, one of his posthumous articles is a book chapter on the subject. Extending the route developed for *aldehydo*-D-glucose pentaacetate, he devised general methods for obtaining crystalline acetates of those sugars in which the carboyl group, aldehydic or ketonic, was present in the free form, uncombined with any hydroxyl group of the sugar chain; and the general chemistry of the hydrated carbonyl group was explored. A synthesis of higher-carbon ketoses by the action of diazomethane on acetylated aldonyl chlorides was established that led to the preparation of acyclic *keto*-acetates that, on deacetylation, gave larger chain ketoses. It was shown that the *keto*-acetates could be used for the synthesis of branched-chain structures. In cooperation with T. M. Lowry of Cambridge University, Wolfrom conducted pioneer work on the optical rotatory dispersion of the acyclic sugar acetates and demonstrated the Cotton effects attributable to the asymmetrically perturbed absorption of the carbonyl group. It was demonstrated that many of the hydrazones and osazones of the sugars were either totally acyclic or contained such a structure as a significant tautomeric form. He recognized at an early stage the potential of nuclear magnetic resonance spectroscopy in structural chemistry and applied it in 1962 to show that an "anhydro-phenylosazone" that had been prepared in his laboratory in 1946 possessed an unexpected, unsaturated phenylazo structure.

The chemistry of the dithioacetals of the sugars was explored in detail, and many useful synthetic transformations were demonstrated. A notable development was the reductive desulfurization of the dithioacetals to the hydrocarbon stage. This reaction was used to establish a major milestone in the chemistry of natural products, the unambiguous correlation between the configurational standards of D-glyceraldehyde for the sugars and L-serine for the amino acids; the correlation was achieved by way of the diethyl dithioacetal of 2-amino-2-deoxy-D-glucose, which was transformed into a derivative of L-alanine without disturbing the configuration of the asymmetric center at carbon atom two.

In the chemistry of dithioacetals Wolfrom also prepared the first dithioacetal of a ketose (D-fructose), and established the technique of mercaptolysis for the fragmentation of polysaccharides. In other hands, the technique of mercaptolysis has been applied successfully for determination of structure, notably with the seaweed polysaccharides agar and carrageenan. The acetylated dithioacetals were shown to be useful characterizing derivatives for the sugars, and subsequent workers have utilized these derivatives extensively for determination of the gross structures of sugars by mass spectrometry. Dithioacetal derivatives were also significant in Wolfrom's work on the structure of the antitubercular antibiotic streptomycin, playing a role in the elucidation of structure of the streptose component. The configuration of the streptidine entity was established by its synthesis from 2-amino-2-deoxy-D-glucose, and further contributions were made on the structure and configuration of the entire streptomycin molecule.

Synthetic methods were developed for amino sugars by displacement of sulfonyloxy groups by nitrogen nucleophiles and applied especially for the synthesis of 2-amino-2-deoxypentoses, until the complete series of eight stereoisomers had been elaborated. Procedures for protecting the amino group were established that led to the successful synthesis of nucleosides containing 2-amino-2-deoxy sugars in the furanosyl form. This work formed part of an extensive program of synthesis of nucleoside analogs having structural variation in the carbohydrate moiety, as potential anticancer agents.

Professor Wolfrom was always concerned with planning research in a logical, orderly way, and he undertook to fill in some of the gaps left by Emil Fischer in the systematic elaboration of the simple sugars. These included the crystalline forms of racemic glucose, racemic glucitol, D-glucose dimethyl acetal, L-fructose, racemic talitol, L-talitol, and xylitol. For key crystalline compounds, he made a special point of recording the data from an X-ray powder diagram as an unequivocal fingerprint of the compound in the particular crystalline modification; he had little faith in syrups unless a suitable crystalline derivative could be prepared. He would accept chromatographic evidence as a tool for monitoring reactions, but only as a preliminary guide to characterization by a definitive method, preferably through a crystalline compound.

Wolfrom investigated a number of problems of technological interest. The formation of color in sugar solutions as present in food products and during sugar refining was investigated. Products of the dehydrating reactions favored by acidity were identified, and the mechanism of the nonenzymic browning (Maillard) reaction between sugars and amino acids was examined; a reactive 3-deoxyhexosulose intermediate was established for the latter reaction, a finding that provided the basis for extensive work in other laboratories. It was demonstrated that the action of alkali on reducing sugars leads to stepwise enolization down the sugar chain. The composition of cane sugar molasses was examined in detail. In a study on the alkaline electroreduction of D-glucose, it was shown that carbonyl groups are reduced completely to the hydrocarbon stage and that a side-product is a twelve-carbon atom derivative formed by way of an aldol reaction.

Electron paramagnetic resonance studies were conducted by Professor Wolfrom and his group on the remarkably stable, free radicals formed when sugars in the solid state are irradiated. The chemical transformations taking place during the controlled ignition of cellulose nitrate were investigated extensively in a project for the armed services. Other nitrated polyhydroxy compounds were also investigated for potential uses as explosive polymers.

The biosynthesis of cotton bolls was investigated by preparing photosynthetically ^{14}C-labeled cotton celluloses. β-D-Glucopyranosyl phosphate, the anomer of the common α-D-glucopyranosyl phosphate, was synthesized; and a synthetic route to L-iduronic acid was devised. Both of these products were subsequently found by others to occur naturally.

New techniques for working with carbohydrates and their derivatives, notably in separation methods, were devised in Professor Wolfrom's laboratory. Extrusive column chromatography was developed as a valuable tool for the separation of mixtures of acylated sugars and was utilized particularly in studies on oligosaccharides, including the characterization of several polymer–homologous series of oligosaccharides. Procedures involving ion-exchange resins were introduced into the carbohydrate field, and the use of microcrystalline cellulose for thin-layer chromatography of unsubstituted sugars was developed. The use of sodium borohydride to reduce free sugars to alditols was first reported by Wolfrom's group, as were the first examples of arsenate, benzeneboronate, and urethan derivatives of the sugars, and the use of absolute hydrogen sulfate as a solvent. Also developed were reliable analytical procedures for the determination of acetyl and methoxyl groups in carbohydrates containing them.

Professor Wolfrom devoted many years to the determination of the structure of various polysaccharides. The most challenging of these was heparin, the natural blood anticoagulant. Methods were found for modifying the intractable "backbone" chain of this polymer, notably by use of diborane to reduce the uronic acid moieties, to give a derivative amenable to structural characterization by the method of fragmentation analysis. By means of crystalline disaccharide fragments that were unequivocally characterized, it was shown that *N*- and *O*-sulfated 2-amino-2-deoxy-D-glucopyranose and D-glucopyranuronic acid residues, connected by α-D-(1 $\rightarrow$ 4) linkages, are present in the polymer, and that L-iduronic acid residues also occur. Other animal polysaccharides investigated by Wolfrom were chondroitinsulfuric acid and the galactan of beef lung.

Molecular structures of starch and glycogen were extensively investigated; evidence for the branch points at carbon atom six was placed on a firm, crystalline basis by the method of fragmentation analysis. Incidental to this work, the nature of reversion of sugars by acids was interpreted. Synthetic confirmation of the structure of the branch-point disaccharide, namely isomaltose, involved the difficult step of introducing the α-D-linkage in the interglycosidic position; this was achieved by a modification of the Koenigs–Knorr synthesis, with the use of a nonparticipating protecting group at carbon atom two in the glycosyl halide derivative. A similar approach was subsequently used for the synthesis of panose, a trisaccharide fragment involved at the branch points in the polysaccharide. Structures were also established for the mannan and arabinogalactan of the green coffee bean, and the presence of these polysaccharides in commercial coffee extracts was established.

Detailed structural investigations were made on British gums, produced commercially by heat treatment of starch. In the quest for novel derivatives of starch having potential utility in industry, various acetal and unsaturated ether derivatives were studied, and routes were developed for the synthesis of amino derivatives of starch having the hydroxyl group at carbon two replaced by an amino group; the latter were used for preparing polymers having structures related to that of heparin. In the cellulose field, comparative studies were made on various series of cello-oligosaccharide derivatives as models for the parent polymer; these investigations included oxidation with alkaline hypochlorite as related to the industrial extraction and bleaching of cellulose fibers.

Professor Wolfrom had a long-standing interest in the pigments occurring in the osage orange (*Maclura pomifera* Raf.), a common hedge-tree found in Ohio. The chemical nature of two complex phenolic pigments present in the fruit of this plant was elucidated, and a synthesis of their skeletal components was effected. These compounds were the first for which it was established that isoprenoid units were condensed on the nucleus of a common plant-pigment, in this case, an isoflavone; other examples have since been found in plants. Three phenolic pigments containing isoprene units condensed on a xanthone nucleus were discovered in the root bark of the same plant, and it was found possible to elucidate their structures, mainly by use of spectroscopic techniques; one of the pigments was synthesized. Two of them were found to contain an isoprenoid unit in the form of a 1,1-dimethylallyl group; they were the first examples discovered of natural phenolic compounds so constituted.

In 1948 Wolfrom assumed the duties of Head of the Organic Division in the Department of Chemistry at The Ohio State University, the department then being under the chairmanship of a physical chemist, Edward Mack, Jr., who, in 1941, had succeeded William Lloyd Evans as departmental chairman. Wolfrom's responsibilities included coordination of the courses and of the requirements for graduate degrees in organic chemistry. He also served for many years on the departmental Library Committee. Thorough as always in the tasks he undertook, he played an important part in developing an excellent chemistry library, both as regards the extent of coverage and the completeness of the collection of early books and periodicals. In 1960, Wolfrom was named Research Professor, and the responsibilities of the Organic Division were passed on to M. S. Newman. In his new position, Professor Wolfrom was able to concentrate more on his individual teaching effort at the graduate level, although he continued to present courses in the chemistry of carbohydrates. His office was a very modest one, in a long corridor of small research laboratories affectionately known to successive generations of occupants as "Sugar Alley." He spurned the opportunity to move into more spacious and modern quarters when the new Evans Laboratory was added to the department in 1960; he felt a sentimental attachment to the antiquated laboratories whose dust was, as legend had it, rich in the seeds of myriad crystal species. Fact or fiction, there is little doubt that the Wolfrom group had an impressive record of success in bringing recalcitrant syrups of sugars to crystallization.

Professor Wolfrom influenced the carbohydrate field in many ways far beyond even his own exceedingly prolific contributions to its literature. He provided the motivation for many others to pursue work in the area. A surprising number of the persons who, at one time or another, have worked in Wolfrom's laboratory have continued independent research on the carbohydrates; those in academic positions include H. El Khadem (Houghton), A. B. Foster (London), S. Hanessian (Montreal), R. U. Lemieux (Edmonton), G. E. McCasland (San Francisco), R. Montgomery (Iowa), K. Onodera (Kyoto), A. Rosenthal (Vancouver), F. Shafizadeh (Montana), the late J. C. Sowden (St. Louis), W. A. Szarek (Kingston), J. R. Vercellotti (Virginia), R. L. Whistler (Purdue), and D. Horton (co-author of this memoir).

Exceptionally well organized, Professor Wolfrom hated wasting time. He handled much of his business by telephone, even with persons in the room next to his office. These calls would be brief and often blunt, as were his letters and notes; he always made his point with maximum impact in as few words as possible. Although he derived great satisfaction from his work, chemistry was by no means Professor Wolfrom's sole preoccupation. He read widely in the classics and history and enjoyed building a fine library in his home. Not an instrumentalist himself, he nevertheless shared his wife's love of music and worked with her in helping the development of the Columbus Symphony Orchestra and in other musical and cultural activities in the community. Together, they also enjoyed the theater, ballet, and the fine arts, both in the local community and during their travels. The Wolfroms frequently received groups of colleagues, students, and visiting scientists in their spacious home on the north side of Columbus. Mrs. Wolfrom, a most gracious hostess, would often entertain the guests with a musical recital at the piano, and Professor Wolfrom was happy to show guests the pleasant garden, the cultivation of which was a source of great enjoyment to him. On other occasions, he would lead the members of his research group and their families on picnic trips into the surrounding Ohio countryside; these expeditions were strictly recreational, although it must be said that, should Wolfrom spot some osage-orange trees along the way, a "work gang" might rapidly be delegated to collect samples.

Five children were born to the Wolfroms: Frederick (who died shortly after birth), Eva Magdalena, Anne Marie and Betty Jane (who were twins), and Carl Thompson.

Because of Wolfrom's precise style of writing and his concern for an accurate historical record, he felt the need for a periodic series of authoritative articles on various aspects of research on the carbohydrates, to be written by qualified specialists and supervised editorially through a rigorous policy in order to ensure extremely high standards of consistency and accuracy. As a result of this idea, near the end of World War II the *Advances in Carbohydrate Chemistry* series was developed. The policies were formulated by an Executive Committee consisting of W. L. Evans, H. O. L. Fischer, R. Maximilian Goepp, Jr., W. N. Haworth, and C. S. Hudson, together with Wolfrom and his co-editor, W. Ward Pigman. With the enthusiastic help and collaboration of publisher Kurt Jacoby and the then-fledgling Academic Press, the first issue of the series was launched in 1945. Wolfrom remained a prime mover in this annual series for the rest of his life and was editor or co-editor of all volumes through Volume 24, except for those of 1950 and 1951. Under his guidance, the series has reflected all of the major significant developments in carbohydrate chemistry and biochemistry, through timely contributions written by authorities in the field. His broad knowledge and critical ability, his attention to editorial detail, and his insistence on "getting it right," have given the series an excellent reputation for quality and reliability. Not even the most eminent authors were immune from his pungent remarks if their manuscripts failed in any way to meet the standards demanded. His respected colleague Claude S. Hudson worked closely with Professor Wolfrom on the early volumes of *Advances;* following the death of Hudson, in 1952, Wolfrom invited R. S. Tipson to join in editing the series. The Wolfrom–Tipson editorial partnership for *Advances* continued for eighteen years thereafter. With the addition of representation from the British Isles on the board of *Advances,* starting with the second volume in the series, a close link was established between British and American carbohydrate chemists that in subsequent years led to much fruitful cooperation, especially in the field of carbohydrate nomenclature.

In collaboration with R. L. Whistler, Wolfrom served as co-editor or consulting editor for the series *Methods in Carbohydrate Chemistry.* These collections of experimental procedures in the carbohydrate field have proved an invaluable standby for research workers. The international journal, *Carbohydrate Research,* inaugurated in 1965, also received strong support from Professor Wolfrom, who served on its Editorial Advisory Board.

For a quarter of a century, Professor Wolfrom worked on the systematization and codification of carbohydrate nomenclature. He was a member of an American Chemical Society committee chaired by R. C. Hockett that developed, during the period 1945–1948, the rules of carbohydrate nomenclature that the society's council approved in 1948. The committee continued to consolidate and extend the rules, this time in cooperation with chemists in Great Britain, and in 1951 Professor Wolfrom became chairman of the committee. The joint study of carbohydrate nomenclature by British and American chemists furnished an excellent example of effective cooperation to improve the language of science for clear and exact reporting of scientific information. A set of rules under joint British–American sponsorship was published in 1953, and as a result of continued cooperative work the rules were extended and further clarified; a revised set of jointly approved rules was issued in 1963.

Wolfrom's committee then continued to work in the development of nomenclature systems for the carbohydrates, in order to accommodate the special requirements of newly developing research areas and to encompass areas, such as the polysaccharides and conformational terminology, not covered in the published rules. At the same time, he sought to develop full international acceptance of the rules by working actively with the Special Committee on Carbohydrate Nomenclature of the Organic Commission of the International Union of Pure and Applied Chemistry. He met several times with the international committee and laid much of the important groundwork for the set of international rules drafted by that body.

In 1959 Professor Wolfrom assumed the duties of Section Editor for the carbohydrates section of *Chemical Abstracts,* a task that he undertook with characteristic thoroughness. All abstracts for that section were carefully checked to ensure that the names used conformed to the approved terminology, and the scientific content of the abstracts was also checked, usually against the original article. Not infrequently, he himself rewrote those abstracts he found unsatisfactory. In 1964 he was made a member of the Board of Advisors for *Chemical Abstracts.*

For his outstanding services in the field of chemical documentation, Professor Wolfrom received in 1967 the Austin Patterson Award, sponsored by the Dayton section of the American Chemical Society. At the award ceremony, many of his old friends and colleagues were present, including Dr. W. A. Hammond, his high school chemistry teacher.

Besides his contributions in the field of chemical documentation, Professor Wolfrom served on numerous committees and held a number of offices in professional societies. From 1940 until 1945, he was an Official Investigator of the National Defense Research Committee. A member of the American Chemical Society, he served as Chairman of the Columbus section and also of the Cellulose Division in 1940, and of the Division of Sugar Chemistry in 1948. In 1958 he was Chairman of Symposium I of the International Union of Biochemistry, in Vienna, and for this he was honored by a citation from the Austrian government. He was a member of the American Society of Biological Chemists, Phi Beta Kappa, Sigma Xi, Phi Lambda Upsilon, Pi Mu Epsilon, and Alpha Chi Sigma. He was a member of the National Committee of the Phi Beta Kappa Book Award in Science from 1961 to 1963 and served as its Chairman in 1963. He was a Fellow of the American Academy of Arts and Sciences, the New York Academy of Science, the Ohio Academy of Science, the American Association for the Advancement of Science, and The Chemical Society (London). In 1959 he was an invited lecturer in the Biochemistry Department at Tufts University Medical School in Boston, Massachusetts.

Numerous other honors and recognitions for his work were bestowed on Professor Wolfrom. In 1950, he was elected to the National Academy of Sciences, and, in 1952, was presented the Honor Award (now the Hudson Award) of the Division of Carbohydrate Chemistry of the American Chemical Society. In 1965, he was honored by The Ohio State University by being named Regents' Professor, a title created at that time to recognize exceptional distinction in scholarly activity at the university. In 1967, he was honored by the Kansas City section of the American Chemical Society with the Kenneth A. Spencer Award for his contributions to agricultural chemistry.

Still at the height of his effectiveness as a scientist, Professor Wolfrom was, in mid-1969, actively planning new research programs to take effect beyond the nominal age for retirement at seventy years. Tragically, an aortic aneurysm, found during a routine physical examination, ruptured several days after its discovery, just hours before a proposed surgical repair could be effected; Professor Wolfrom died in Columbus on June 20, 1969. It is particularly indicative of his methodical and organized personality that, on the day before he was to enter the hospital, he visited each of his research students to plan work for the following few weeks, answered all of the correspondence on his desk, and left instructions for handling the various items of business that were expected to arise. He was survived by his widow, four children, three sisters, and seven grandchildren.

A special issue of the journal *Carbohydrate Research,* comprised of research contributions by former students of Professor Wolfrom's, was published as the Wolfrom Memorial Issue in April 1970, on the seventieth anniversary of his birth. Also dedicated to his memory was the program of papers presented in Toronto, Ontario, in May 1970, at the joint meeting of the Carbohydrate Division of the American Chemical Society and the Canadian Institute of Chemistry. In addition, a special tribute to him was paid at the Fifth International Conference on Carbohydrates held in Paris in August 1970.

Professor Wolfrom's life was a noble example of devotion to the pursuit and advancement of science. His dedicated and sincere personality won the response and admiration of those who had the privilege of knowing him. His important contributions to carbohydrate chemistry will remain a permanent record in the annals of chemistry. He has erected to his name an enduring memorial and has left impressed in the pages of science a monolithic achievement that can serve as an inspiration and a challenge to others. Even more important, his spirit and ideas made a lasting influence on a whole generation of new scholars, so that the qualities for which he stood can continue to flourish.

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