NATIONAL ACADEMY OF SCIENCES

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1881—1952

A Biographical Memoir by

LYNDON F. SMALL AND MELVILLE L. WOLFROM

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WASHINGTON D.C.

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January 26, 1881—December 27, 1952

BY LYNDON F. SMALL AND MELVILLE L. WOLFROM

WITH THE PASSING of Claude S. Hudson, American chemistry lost one of its ablest representatives, one whose brilliant researches had a predominant influence in the modern carbohydrate field for over forty years. Seldom is there found in a devoted scientist such a combination of friendly personality, keen wit, and complete disregard for restricting conventions. His long and delightful stories, both proper and ribald, will long be remembered by those privileged to have heard them. Although of modest and unassuming manner, Hudson took great pride in the perfection of his work, and in the honors which he received, and showed an almost naive pleasure in the ceremonies connected with his numerous awards. In view of Hudson's reticence concerning his personal history, it is fortunate that H. O. L. Fischer was able to induce him to furnish a record of his life in connection with the publication of his collected papers in 1946.

Claude S. Hudson, the second child of William James and Maude Celestia (Wilson) Hudson, was born January 26, 1881, in Atlanta, Georgia. His father's ancestry was Scottish, that of his mother a mixture of English, Scots, and Huguenot French. Shortly after the War between the States, William Hudson moved from his early home in South Carolina to Georgia and, when Claude was about three years old, took his family to Mobile, Alabama.

In this small southern city at the head of Mobile Bay, Claude and his older brother William spent their youth close to nature in an atmosphere of peace and plenty. Hudson writes with nostalgia of the long southern summers and mild winters, with the opportunities for swimming, fishing, and boating. It seems probable that Hudson's later love of nature and its manifestations was deeply rooted in this boyhood, though one might often suspect that his unusual knowledge of botany was acquired because of a surmise that this or that species of plant might contain some new sugar.

At high-school age he entered the University Military School for college preparation, and came under the influence of Julius T. Wright, an ideal type of educator and character builder. The secretary of the Mobile Y. M. C. A., the Rev. A. C. Harte, was also a close friend, whose culture and charm left a deep impression.

With a strong religious background and a great interest in church activities, Hudson decided to study for the Presbyterian ministery, and chose Princeton University for his preparation. There he enrolled for the B. Sc. degree in 1897 and, as he himself states, a more naive and gullible freshman never entered the University. He was a friendless soul in a land of strange customs and stranger speech, speaking a dialect that his classmates found equally strange.

In this freshman year he fought homesickness by strict devotion to his prescribed studies, and in particular became so interested in the inspiring chemical lectures and demonstrations of Professor L. W. McCay that he decided in all sincerity that the best way to train for the ministry would be to acquire all the science possible. Perhaps at this point a good minister was lost, for Hudson later had a striking ability to make any topic whatsover interesting to his listeners.

After a summer helping his friend Mr. Harte in his duties as chaplain of the Second Alabama Regiment (Spanish-American War), he returned with new vigor to his scientific program, with a feeling that he had no talent for Christian work. During the ensuing three years he became so fascinated by his studies in chemistry, physics, astronomy, geology, and mathematics under a distinguished group of teachers that the idea of the ministry was completely abandoned in favor of a scientific career.

Shortly before his graduation from Princeton in 1901, Hudson began to realize that the prospects for a future in science were indeed scanty for an unknown young bachelor of science coming out into a world where he had no influential connections, and he applied to his old friend Mr. Wright for an instructorship at the University Military School in Mobile. Scarcely had he been accepted in this capacity, when he was offered appointment to the Princeton Class of 1860 Fellowship in Experimental Science. His release from the Mobile obligation was easily arranged, and in the fall of 1901 he entered upon the duties of the Fellowship.

Hudson's interest at that time was primarily in physical chemistry, a phase that was totally neglected by the Chemistry Department, and he therefore chose to work in the Physics Department, in collaboration with Professors E. H. Loomis and William F. Magie. This was a critical decision, both for Hudson and for carbohydrate chemistry. It was here, during the purification of a sample of milk sugar, that Hudson observed the already known but unexplained phenomenon of mutarotation. His curiosity aroused, Hudson begged permission to explore this, and conducted an investigation of the forms of milk sugar which did not explain mutarotation, but committed him to sugar chemistry, and resulted in his first publication, in the *Princeton University Bulletin*. In June, 1902, he was awarded the Master of Science degree.

Hudson's parents were eager to have him continue his studies abroad, and believed that with the strictest economy they might be able to support such a program for three years. On the advice of Professor Loomis it was decided that Hudson should go to Nernst's institute at Göttingen. In Nernst's laboratory he continued his work on the mutarotation of lactose, and in return he and an American colleague taught Nernst to play poker, as preparation for an impending trip of Nernst to America. They did not, however, succeed in convincing the worthy professor of the danger of being scalped by the Indians around New York.

In the spring of 1903, Hudson learned that his father's financial situation had become unfavorable, and that his stay in Europe must be limited to one year; he and Nernst then agreed that it would be advantageous for him to spend his second semester with Van't Hoff in Berlin. Before leaving Göttingen, Hudson was able to visit for a short time in the laboratory of Gustav Tammann, where he demonstrated the closed-ring solubility curve of the nicotine-water system. This resulted in one of the few publications made by Hudson which were not concerned with some aspect of carbohydrate chemistry.

While in Berlin, Hudson had the opportunity to meet Emil Fischer, at the International Chemical Congress, although he did not realize at the time what a profound influence Fischer's work would have on his later activities. Here also he became acquainted with Professor A. A. Noyes, and was successful in obtaining a research assistantship in the new Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology.

At Boston he was able to continue some of his work on milk sugar, but his proposal to extend his studies to mannose had to be denied because of lack of funds. With the aid of Professor Magie, Hudson returned to Princeton as an instructor in physics (1904–1905). This was followed by two years in a similar capacity at the University of Illinois. In 1906 Hudson had married Alice Abbott, of Urbana, and even in those times was having difficulty in getting along on a salary of $900 a year. Moreover, he was now certain that his inclination and ability were far more toward chemistry than physics. In desperation, he was on the point of abandoning a scientific career and entering his father's phosphate mining business, when he received an offer from his former Göttingen colleague, John Clement, to join the U. S. Geological Survey as a physicist. In the transition, Hudson stopped at Princeton long enough to take his final examination for the Ph. D. degree, *magna cum laude* (1907). The government position was of short duration because of reduction in force. There followed a brief interval of industrial employment in physical and chemical testing of asphaltic substances at Perth Amboy, N. J.

In 1908, Hudson secured an appointment in Washington, as a routine analyst in Harvey W. Wiley's "poison squad," investigating adulteration of foods. This work Hudson was able to so systematize that, with the cooperation of a sympathetic supervisor, he could devote considerable time to studies of the hydrolysis of sucrose by invertase. Dr. Wiley himself became interested in this work and provided an assistant, and C. S. Hudson was really launched on his carbohydrate career.

In 1911–1912, Hudson took leave of absence to serve as Acting Professor of Physical Chemistry at Princeton, substituting for Professor G. A. Hulett. This was a most unusual course in physical chemistry. Hudson lectured for some weeks on subject matter with which he was familiar, then, having reached the bottom of the barrel, announced that the class did not know enough German ever to get anywhere, and for the remainder of the term taught chemical German.

Hudson's year at Princeton was by no means a loss, for he assembled a group of enthusiastic co-workers, some of whom followed him on his return to the Bureau of Chemistry, where in 1912 Dr. Carl L. Alsberg, successor to Dr. Wiley, established the Carbohydrate Laboratory. Hudson's recondite researches were supported to the utmost by Dr. Alsberg, as they were later in the Public Health Service, even though they had little direct bearing on the enforcement of the pure food laws or the health of the nation.

With the advent of war in 1917, Hudson was loaned to the War Department for crucial experiments on activated carbon for gas masks, and for four years after the war he acted as a consulting chemist on decolorizing carbon, yeast, and brewing problems. Beer was a subject of great personal interest to him, and during the prohibition era he maintained a special refrigerator set to the optimum temperature to produce a sound brew (at least in comparison with most beer of this period).

In 1923 Hudson was called to the National Bureau of Standards by Frederick J. Bates, Chief of the Polarimetry Section, to carry out research studies on sugars, an opportunity which he accepted with delight. With the exception of a year spent in the Hawaiian Islands consulting on problems of the pineapple canning industry, this fruitful research period extended until 1928. Hudson attracted many brilliant young scientists whose names and discoveries were later to become well known in carbohydrate chemistry. He always worked with his own hands as well as with his brain, and transmitted his patience and extraordinary skill to his collaborators. It is said that in spite of his care in handling rare sugars, he once upset a small beaker of viscous sirup in the center of his office desk. Perhaps as an object lesson, he wrote and worked for months around this sticky mess, until it finally crystallized and could be removed without loss.

The high reputation which Hudson had acquired from his researches at the Bureau of Standards had an unexpected result. In 1928 he received an invitation from Dr. G. W. McCoy, Director of the Hygienic Laboratory, to serve as Professor of Chemistry in the U. S. Public Health Service, a position which had recently been vacated by Professor William Mansfield Clark. Hudson had a difficult decision to make, for the Hygienic Laboratory was primarily a medical institute dealing with practical problems of public health. One might easily question whether such an organization would long support fundamental studies in sugar chemistry. There was precedent, however, in P. A. Levene's basic researches on carbohydrates at the Rockefeller Institute for Medical Research and, at the Hygienic Laboratory itself, in the outstanding contributions of Clark on oxidation-reduction systems. The chemistry of carbohydrates, moreover, is closely connected with human nutrition. Hudson accepted the offer of Dr. McCoy, a decision that he never had occasion to regret.

During his last months at the Bureau of Standards, Hudson had succeeded in preparing several kilograms of the rare trisaccharide melezitose from "gritty honey," and with the collusion of several associates he quietly took this along when he moved. This caused considerable trauma, which ultimately healed.

Early in 1929 Hudson was firmly established with twelve coworkers at the Hygienic Laboratory (later National Institutes of

Health), and here began the most productive and happy years of his career. With the small load of administrative work that was involved, he was able to devote his time almost entirely to his beloved sugars and enzymes. The practical problems of chemistry in public health which came along he turned over to his long-time associates, Dr. Elias Elvove and Mr. C. G. Remsburg.

It was in this period, from 1928 until his retirement in 1951, that the major portion of Hudson's brilliant researches was accomplished, in association with Raymond M. Hann, Nelson K. Richtmyer, and Hewitt G. Fletcher, Jr., as well as many others whose names appear in the appended Bibliography. He exercised extraordinary care in the preparation, purification, and characterization of his products, and was equally meticulous in the publication of his results. He often said, "I don't like to report in the literature any experiment until I have been through it at least three times." He set similar standards for his co-workers, and was extremely intolerant of experimental failures resulting from poor technique or carelessness. Indeed it was frequently remarked of him, "Huddy is a wonderful friend, but a hard master to work for." In one instance, after many months of waiting, a co-worker obtained a seed-crystal of a rare sugar, and thus brought the whole product to crystallization. Without saving a crystal, his assistant brought the entire mass into solution for purification—and the whole waiting period had to be repeated. For days Hudson wandered around, muttering, "He threw away his bait, threw away his bait."

In his relationships with his fellow scientists, Hudson insisted upon the same rigid principles of precision and clarity that were exemplified in his own writings, but his criticism was often tempered with humor. An editor who became somewhat impatient for a review of a rather mediocre book on carbohydrate chemistry received the reply, "I have the book you refer to, and have placed it upon the shelf between the volumes of Emil Fischer's collected work, hoping that by the process of osmosis there may result something worth reviewing." To a colleague who had hitherto not published in the sugar field, and who wished an opinion on a manuscript, he wrote "Dear L.: I have read your paper carefully, and my first suggestion would be a change in the title. This should read 'Alice in Sugarland.' "

Hudson's fascinating anecdotes were occasionally built against a sugar background. A favorite whimsy was that two Hudsons dwelt in opposed mirrors from which they emerged at appropriate times. The L-Hudson was the convivial one who partook of intoxicating beverages, was strongly attracted by beautiful women, and was in general sinful. D-Hudson was the serious, sober, gentlemanly scientist. On the occasion of the Organic Symposium of the American Chemical Society at Richmond, L-Hudson was in charge. It became necessary for him to leave the auditorium, but alas, the only inconspicuous exit was a spiral staircase which was dextro-rotatory. With the help of friends he finally mounted this, but claimed for years that he had been racemized in the process.

In the later years of his life, although he was not in good health, Hudson's amazing productivity continued unabated. He regularly attended meetings of the American Chemical Society, although he usually left the presentation of papers to his younger co-workers. He was also active in the Starch Round Table, an annual meeting in some secluded place, of those interested in the chemistry of starch and other carbohydrates. In the time which he spared from scientific work, he took pleasure in ambling through the spring woods, or along the semitropical littoral at Kitty Hawk, North Carolina, identifying shrubs and woods plants, floating in the warm waters bordering the Gulf Stream, or speculating on the amounts of glucosamine that might be obtained from the waste of the crab meat canneries.

After retirement at the age of seventy in 1951, he still led a busy, though necessarily quiet, life. He maintained a small laboratory at the National Institutes of Health, but was chiefly occupied with writing manuscripts from accumulated data, and with editing a new volume of *Advances in Carbohydrate Chemistry*. During this period he also acted as consultant for a Midwest brewing firm. His activities were terminated by sudden death from a heart ailment on December 27, 1952.

Hudson was married four times, the first three of these marriages ending to his regret in divorce. His last marriage, in 1942, was to his childhood sweetheart, the then widowed Erin Gilmer Jones of Selma, Alabama. This last marriage was a happy one. By his first marriage he had three children: a son, William Abbott, and two daughters, Alice and Sally. His son William died in England in 1945 while serving in the U. S. Air Force. Hudson is survived by his daughters and his wife Erin.

Although most of Hudson's research was abstruse, its fundamental nature and importance were early recognized. It struck into the actual basis of life, nutrition, by way of starch, sugars, enzymes, fermentation, vitamins, and the energy cycle (ribose). He was elected to the National Academy of Sciences in 1927, to the Kaiserlich Leopoldinisch-Carolinisch Deutsche Akademie der Naturforscher (Halle) in 1932, and became an Honorary Fellow of the Chemical Society (London) in 1949. He was a charter member of the Academy of Medicine of Washington, D. C. (1936) and received the D. Sc. from Princeton University (1947). By the American Chemical Society, he was awarded the Nichols Medal of the New York Section (1916), the Willard Gibbs Medal of the Chicago Section (1929), the Hillebrand Prize of the Washington Section (1931), the Richards Medal of the Northeastern Section (1940), and the Borden Medal in 1941. The Franklin Institute of the State of Pennsylvania bestowed on him the Cresson Medal in 1942. The United States Government made him the first recipient of the Federal Security Agency Award, and industry honored him with the Grand Prize of the Sugar Research Foundation. After Hudson's death, the Division of Carbohydrate Chemistry of the American Chemical Society renamed its annual award "The Hudson Award" in memory of the first award of the Division, which was made to C. S. Hudson in 1946. He served as an associate editor of the *Journal of the American Chemical Society* and of the *Advances in Carbohydrate Chemistry*. He was chairman of the Organic Division of the American Chemical Society (1934) and served on several of the organic nomenclature committees of the Society.

The sixty-fifth birthday of Hudson was celebrated by a carbohydrate symposium and by the publication in book form of the 247 papers which had originated up to 1945 from his Laboratory. These two volumes may well take their place on the library shelf beside those of Emil Fischer's collected work, with which they may be considered isotonic. One of the principal banquet speakers on this occasion was Sir Norman Haworth, a loyal friend of Hudson in spite of their disagreement many years ago. In 1951, at his seventieth birthday, the time of his official retirement, Hudson's friends and colleagues again gathered in his honor at the National Naval Medical Center.

The carbohydrates constitute a group of carbon compounds that are essential to life and are concerned especially with energy transfers in animal and plant metabolism and in the chemical fixation of carbon dioxide under the influence of the radiant energy of the sun. Many chemists have made their contributions to the study of these substances, but Emil Fischer, Sir Norman Haworth, and Claude S. Hudson occupy prominent positions in the development of the structural chemistry of the carbohydrates. These men furnished inspirational leadership to many associates and trained investigators for the continuing work in this field. The great contribution of Emil Fischer was to establish the stereochemistry of the basic carbon chain in the *Bausteine* or monosaccharides of this group. Sir Norman Haworth utilized methylation techniques to determine the ring sizes of the monosaccharides and to fix the points of glycosidic union in the principal disaccharides and polysaccharides. Claude S. Hudson gave his main attention to the nature of the stereochemistry of the reducing or hemiacetal carbon of the sugars.

Hudson began his work by studying certain physicochemical aspects of sugar solutions, utilizing first the two known crystalline forms of the disaccharide lactose. It was shown that the mutarotation, in aqueous solution, of these anomeric forms, followed first order kinetics with the specific reaction constant being the same for either form. These studies were later extended, with like results, to the anomeric forms of D-glucose. Hudson then elaborated his theory of the maximum rate of solution whereby the rotation of an unknown anomer could be evaluated by measuring the solubility and polarimetric changes with time in a solution saturated with respect to the known anomer. The mutarotation of D-glucose in water was shown to be subject to general acid-base catalysis expressible in the equation

$$k=0.0096+0.258[H^+]+9750[OH^-].$$

This equation shows that the catalytic activity of hydroxyl ions is 40,000 times that of hydrogen ions and the first term of the equation allows the ionic dissociation of water to be evaluated as 1.0×10^{-14} at 25°. Continued interest in the solid phases of sugars led to the establishment of molecular compounds between them and to interesting studies on the anomeric nature of sugar racemates. The sugars form molecular compounds with halides and a number of these were characterized as to anomeric form; an unstable hydrogen chloride addition compound of methyl α-D-fructofuranoside was encountered.

In the course of these studies, concerned essentially with the physicochemical properties of sugar solutions, it was necessary to prepare numerous sugars in a high state of purity. Thus arose the many publications concerned with the preparation of sugars from their natural sources. Sugar chemists know that these preparative directions of Hudson are exact and unfailing, and they have been of inestimable value. Strangely, Hudson received some criticism of these publications and even had a few refused by editors on the grounds that the directions, which indeed made the difference between crystals at the finish or no crystals, were of insufficient novelty. His last publication along these lines appeared in 1951 and was entitled

"Improvements in the Preparation of L-Arabinose from Mesquite Gum."

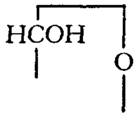
Hudson was always a lone worker and was a member of no school. His early training in physics gave him an exactitude in measurement and thought, while his association with the great and imaginative Van't Hoff, though short, exerted a profound impression upon him. Van't Hoff had published some speculations on "optical superposition" or the possible additive nature of optical rotatory power. More data were required, and Hudson recognized that in the carbohydrates there was at hand the largest known group of optically active isomers of known configuration which would be ideal for the further exploration of these effects. In his lactone rule formulation he noted that the optical rotatory sign of an aldonic acid lactone, of significant rotation, was controlled by the configuration of the carbon bearing the hydroxyl group involved in the ring closure. The rotatory sign of the amides, phenylhydrazides, and benzimidazoles of the aldonic acids was shown to be conditioned by the configuration of the center adjacent to the carboxyl function.

That part of the study of the relation between structure and rotatory power which occupied Hudson for the greater part of his life was concerned with the contribution made by the anomeric carbon center of the sugars. It was elaborated in his rules of isorotation, which state that if the rotation is divided into that (A) contributed by the anomeric center and that (B) of the remaining centers, then, in any anomeric pair, the sum of their molecular rotations is a constant characteristic of the B portion and the difference is a constant characteristic of the A part.

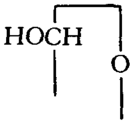
$$\text{For the } \alpha\text{-D anomer, } A+B=[M]$$

$$\text{For the } \beta\text{-D anomer, } -A+B=[M]$$

When Hudson began this work, anomeric forms had frequently not been well separated and a state of confusion existed in their nomenclature. He brought order in with his rule, originally empirical, that the more dextrorotatory (D series) member of an anomeric pair was to be designated α and its hydroxyl, or substituted hydroxyl, was to be written to the right in the Fischer projection formula.



α-D

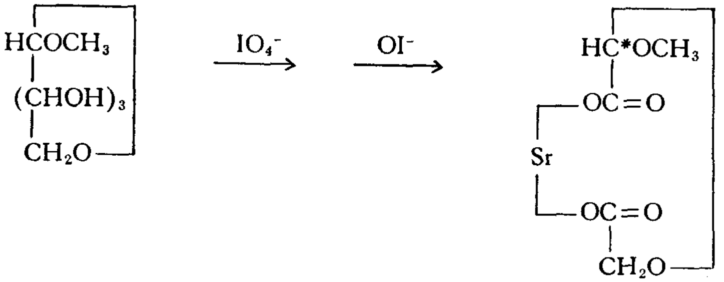


β-D

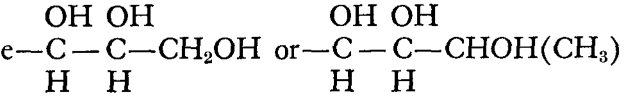
These modified rules of optical superposition were found to have limitations because the effects were partly constitutive and not strictly colligative. Nevertheless, they hold remarkably well in closely related structures and are infallible for making anomeric assignments.

Hudson found in the acetates of the sugars a fruitful source of readily prepared and easily purified anomers. When the acetates failed to yield good derivatives, as in the pentose series, the benzoates proved useful. A handicap to the sugar chemist is the unavailability of many of the fundamental hexose structures. Hudson overcame this by finding most of these structures available in the higher sugars. Thus, while D-gulose is a sirup and difficulty preparable, the "*α–d*-glucoheptose" (D-*glycero*-D-*gulo*-heptose) of Emil Fischer is a readily crystallizable and available sugar which bears the D-gulose structure in its aldose-functioning portion. The first evidence, on a crystalline basis, for a second ring form in a sugar was provided in 1916 by the characterization of the four isomeric pentaacetates, in two anomeric pairs, of D-galactose.

Application of the α–glycol-splitting metaperiodate ion oxidant to the sugar glycosides resulted in a confirmation of their ring size, established first in other laboratories by methylation techniques, and a configurational correlation between anomers of different sugar structures. Thus, it was found that all of the more dextrorotatory anomeric methyl D-pentopyranosides did indeed have the same order of groups about the anomeric carbon. It had been considered that the arabinose structure might provide an exception to the Hudson anomeric nomenclature rules, but this was found to be not the case. The anomeric configurations and ring structures of the unsubstituted sugars are difficult to ascertain by direct methods but insight into this problem was obtained by the initiation of kinetic studies on the oxidation of aldoses with hypobromite ion.



The mysteries of carbohydrate enzymic action always intrigued Hudson. His early studies on the hydrolysis of sucrose with invertase constitute one of the first proofs that enzymic reactions can follow the laws of mass action. He established that the action of invertase on sucrose was irreversible. He studied the rapid hydrolysis of sucrose with massive amounts of invertase (1908–1909) and demonstrated that the D-glucose component was liberated as α–D-glucopyranose and that the D-fructose component initially freed did not correspond to any known form of this sugar. It was later shown in other laboratories that D-fructose was combined in sucrose as the furanose ring form. The anomeric form of the D-fructofuranose component of sucrose was established as β by demonstrating that invertase hydrolyzed only β–D-fructofuranosides, a circumstance which allowed the α–D anomers to be isolated from their synthetic anomeric mixtures. Hudson carried out many studies on the purification of invertase but this problem is still unsolved.

Hudson always insisted on maintaining his carbohydrate research on a crystalline basis. He was therefore greatly pleased when J. B. Sumner prepared jack bean urease in crystalline form and showed that it was an intact protein. He remarked at the time that this formed an important milestone in the development of enzyme chemistry. He was likewise intrigued by the *Bacillus macerans* which produced crystalline cyclodextrins from starches. The enzyme responsible for this action was isolated in extract form and named *Bacillus macerans* amylase. The selective oxidizing action on alditols, undoubtedly enzymic, of the "mother of vinegar" organisms *Acetobacter xylinum* and *Acetobacter suboxydans,* was exploited for synthetic purposes and the latter organism was shown to require the terminal structure  $-\underset{\mathrm{H}}{\overset{\mathrm{OH}}{\mathrm{C}}}-\underset{\mathrm{H}}{\overset{\mathrm{OH}}{\mathrm{C}}}-\mathrm{CH_2OH}$ or $-\underset{\mathrm{H}}{\overset{\mathrm{OH}}{\mathrm{C}}}-\underset{\mathrm{H}}{\overset{\mathrm{OH}}{\mathrm{C}}}-\mathrm{CHOH(CH_3)}$ for action.

Ketoses differ markedly in reactivity from the aldoses. Crystalline acetates of D-fructose were characterized and new fructosides were prepared. D-*altro*-Heptulose ("sedoheptose") was found in *Sedum spectabile* and now occupies a prominent position in the carbon fixation cycle of photosynthesis. D-*manno*-Heptulose and lactulose were synthesized by the action of dilute alkali upon the appropriate aldose. Turanose, one of the disaccharide scission products of the trisaccharide melezitose, was crystallized and shown, by very clever and unique experiments, to be 3-α-D-glucopyranosyl-D-fructose. As mentioned above, other ketoses were prepared by the action of *Acetobacter suboxydans* upon alditols.

In order to establish the configuration of the higher sugars, the preparation of their alditols was requisite and a number of these were characterized. A very comprehensive program on the establishment of the nature of the cyclic acetals of the pentitols and hexitols was carried through successfully and led to the formulation of rules on the relationship between the configuration of an alditol and the structures favored in its cyclic acetals. Reductive desulfurization was utilized to prove that natural polygalitol is 1,5-anhydro-D-glucitol and to confirm the structure of natural styracitol as 1,5-anhydro-D-mannitol. The reaction was extended to other sugars.

The formation of anhydro sugars by the pyrolysis of oligosaccharides and polysaccharides was explored. The *O*-isopropylidene derivatives were found to be useful in their isolation and purification. The main product, from the aldoses studied, was the 1,6-anhydro-β-D-glycopyranose, with an isomeric anhydride also being isolated in the D-galactose series; this was proved later, in another laboratory, to have the 1,6-anhydro-α-D-galactofuranose structure. "Sedoheptulosan," the nonreducing anhydride of "sedoheptose" that was early discovered to be formed in high yield by the action of hot dilute acid on the reducing sugar, was proved to have the 2,7-anhydro-β-D-*altro*-heptulopyranose structure and to be thus related to the 1,6-anhydro-β-D-aldohexopyranoses. D-Altrose, D-*ido*-heptulose, L-*gulo*-heptulose and D-*glycero*-D-*ido*-heptose formed similar anhydrides under acidic conditions. The formation of the 1,6-anhydro-β-D-aldopyranoses by the action of alkali on aryl β-D-aldopyranosides was elaborated. 1,6-Anhydro-2,3-*O*-isopropylidene-β-D-mannopyranose was utilized in the first syntheses of lactose, cellobiose and their 2-epimers.

Hudson early utilized the reaction by which a β-D acetate was converted to an α-D acetate (the reverse occurs in the arabinose structure) by zinc chloride in acetic anhydride. He later preferred sulfuric acid for this anomeric conversion. A striking result was obtained when it was established that aluminum chloride converted the octaacetates of lactose and cellobiose in chloroform solution, into hepta-*O*-acetyl-disaccharide chlorides in which the configuration of carbons two and three of the D-glucose moiety had been inverted.

The optical rotation of one of the pentaacetates of D-fructose did not conform to Hudson's isorotation rules and this was later shown, in another laboratory, to be an acyclic form designated *keto*-D-fructose pentaacetate. Other laboratories then proved that this was the usual occurrence in the direct acetylation of ketoses with acid catalysts at low temperatures. Two hexaacetates of the aldoheptose D-*glycero*-D-*galacto*-heptose, earlier designated *d*-α-mannoheptose, had been prepared in Hudson's laboratory in 1924 by hot acetylation of the aldose with sodium acetate and acetic anhydride. Ten years later one of these was proved to be D-*glycero*-*aldehydo*-D-*galacto*-heptose hexaacetate. Acyclic acetates were encountered in the acetolysis of methyl β-D-arabinopyranoside and in a series of unique reactions these were converted to the first known acyclic acetal in the sugar series, D-arabinose dimethyl acetal.

The greater stability toward acids of the benzoate over the acetate ester group allowed significant studies to be carried out on the reaction of the poly-*O*-benzoyl-aldosyl halides with alcohols.

Triphenylmethyl (trityl) chloride reacts preferentially with primary alcohols but it was shown that it could react also, under "forcing" conditions, with secondary alcohols.

The phenylosazones are greatly overrated for derivatizing sugars. A much better derivative, the phenylosotriazole, was discovered in Hudson's laboratory as an oxidation product of the phenylosazone with cupric ion. Fehling solution is an asymmetric alkaline copper oxidizing agent utilizing a cupric L-(*dextro*)-tartrate complex. Interesting changes were noted when the enantiomorphous D-(*levo*)-tartrate was employed.

Because of his emphasis upon crystalline products, polysaccharides did not interest Hudson a great deal. However, pioneering work was carried out on the periodate oxidation of cellulose and starch.

In the above brief recapitulation of the highlights in the work of the Hudson laboratory, no credit to co-workers or to other laboratories has been cited. The many co-workers' names are to be found in the Bibliography. The work of Claude S. Hudson and his associates will long stand as a monument of rigorous mathematical reasoning, exceptional clarity, and experimental cleverness.

We desire to thank Dr. Nelson K. Richtmyer, of the National Institutes of Health, Bethesda, Maryland, for valued assistance in preparing this memoir.

KEY TO ABBREVIATIONS

Am. Food J. = The American Food Journal
Bur. Standards J. Research = Bureau of Standards Journal of Research
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Biol. Chem. = The Journal of Biological Chemistry
J. Chem. Educ. = Journal of Chemical Education
J. Ind. Eng. Chem. = The Journal of Industrial and Engineering Chemistry
J. Org. Chem. = The Journal of Organic Chemistry
Phys. Rev. = The Physical Review
U. S. Dept. Agr., Bur. Chem. Circ. = United States Department of Agriculture, Bureau of Chemistry Circular
Z. physik. Chem. = Zeitschrift für physikalische Chemie

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