NATIONAL ACADEMY OF SCIENCES

RUDOLPH JOHN ANDERSON

1879—1961

A Biographical Memoir by

HUBERT BRADFORD VICKERY

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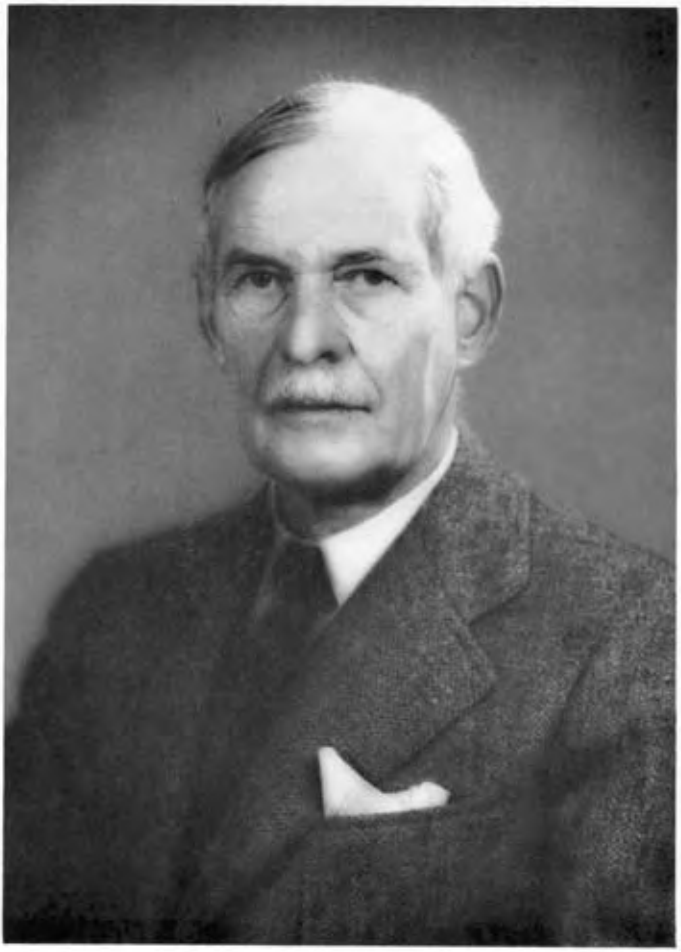

Rudolph J. Anderson

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September 13, 1879–April 6, 1961

BY HUBERT BRADFORD VICKERY

RUDOLPH ANDERSON devoted his life to the investigation of chemical substances found in plants. His work carried on a tradition in organic chemistry which goes back to its earliest days, and which is represented in the history of the science by such distinguished names as that of his fellow-countryman Scheele, by Braconnot in France, by Liebig, Ritthausen, Schulze, and Fischer in Germany, and in more recent years by a large and growing band of devoted investigators in this country and abroad who concern themselves with the stuff that plants are made of. Present-day biochemistry deals mainly with the relationships in the living cell of a host of substances of the most varied nature. But back of this modern approach is the work of the organic chemist who isolated and identified these components, who recognized their significance, and who learned how to deal with them. Such investigations lie at the foundation of our understanding of the processes of nature and of our hope for its future development.

Anderson was born in Harna, Sweden, September 13, 1879, the son of Anders and Johanna Anderson and eldest of a family of four boys and three girls. He was brought up on his father's farm and attended the local country school, where he learned to read and write and to do simple arithmetic, and where he also received a firm foundation in the Lutheran catechism. In 1893, at the age of thirteen, he came unescorted to Boston with no knowledge of the English language, and obtained employment with a family in Cambridge for

whom he worked for room and board during the winters. In summer he worked on their farm in New Hampshire for one dollar a week and board. He attended a grammar school in Cambridge during the winters and graduated at seventeen, but was unable to continue his education in high school.

There followed a period of several years during which he read and studied evenings and worked at various industrial jobs in Cambridge. One of these, a position as laboratory boy and assistant to the young chemist employed by a rubber manufacturing company, was of great significance for his subsequent development. It led to employment with a small pharmaceutical company in Cambridge and, when this concern went out of business, to a position with a manufacturing pharmaceutical company in New Orleans, the staff of which he joined in 1900. Among his papers, Anderson left an amusing account entitled "Adventures in the Education of Rudolph Anderson." He describes this phase of his career as follows:

"I found that I had gotten into more than I had bargained for. In applying for the position, I assumed that the job would be one that I could handle, but on reporting for work, I was appalled to find that I was put in complete charge of production as chief chemist. For such a job I was not prepared, but I had to make the best of it. . . . I was qualified to hold a $15.00 a week job as a technician, which was the salary I had asked for, but my education was totally inadequate for the job that was thrust upon me and which paid me $100.00 a month."

It is clear that the trust given to their new chief chemist by his employers was not misplaced. Anderson stayed with the company for nearly ten years, finally becoming Vice-President and General Manager. He prepared himself for his most immediate responsibilities by after-hours study for the examination of the State Board of Pharmacy and passed this successfully before his first year was out. He then attended night classes at the New Orleans College of Pharmacy and secured their degree in 1903. Next, he arranged his work so that he could attend classes at Tulane University for half-days, and

soon satisfied his professors that his knowledge of chemistry was adequate. The chief obstacle, however, was mathematics. Nevertheless, with the aid of tutoring, he succeeded in fulfilling the requirements and was graduated with the class of 1906. For his language requirements, he had offered Spanish, which he had studied in class, and Swedish. Anderson's report on this incident is:

"I learned afterwards that the faculty had serious doubts about allowing Swedish as a modern language. It was argued that, as no one at Tulane knew any Swedish, they could not tell whether I knew the language or not, but my application was granted and I never had to pass any examination in Swedish."

For his thesis, which he chose to do in bacteriology, he prepared an essay entitled "The Common House-fly Considered as a Carrier of Bacterial Infection." This investigation, his first, is described:

"I managed to catch a large crate full of flies in the early fall which I kept in the laboratory. The flies did not seem to like living in a screened cage and their mortality was appalling. After a couple of months I had only a few flies left alive. It was necessary therefore to proceed with haste from a study of the flies' anatomy to a demonstration that flies actually could transmit bacteria. My few remaining flies were so weak that they could hardly walk, but I succeeded in inducing a couple of them to waddle across a sterile agar plate which was then carefully incubated. The results were most satisfactory. Every footprint of the flies left a magnificent track of bacterial growth on the surface of the plate."

A copy of this essay survives. It is written in impeccable English and is a tribute to the quality of the teaching he had received at Tulane, a matter that Anderson himself emphasizes. The foundation of his later eminence as an editor was thus securely laid.

The next year was spent doing part-time graduate work, mainly in theoretical chemistry, but Anderson soon came to realize that only study abroad could give him the broad knowledge of chemistry and the advanced degree that he felt was essential. Accordingly, the next two years were spent in accumulating a sum sufficient for this, and

in the summer of 1909, with $1800 saved, he returned to Sweden and applied for admission at the University of Uppsala as a candidate for the doctor's degree. Here he met with frustration. Although he was allowed to work in the laboratory, his application was repeatedly declined. On a final attempt, the authorities reconsidered but, since he had offered English as a minor, they insisted that he should study Latin for three years, as this was their minimum requirement for acceptance of an English minor. Thus, after wasting the greater part of a year and becoming thoroughly discouraged, he finally followed the advice his professor at Tulane had given him and went to Berlin.

He was admitted without difficulty into Emil Fischer's laboratory and, as Fischer's group of students was already filled, was turned over to Hermann Leuchs as preceptor. He was assigned a problem on the chemistry of the color reaction of brucine with nitric acid, and there followed a year and a half of a busy and exciting life, during which he perfected his knowledge of German, made many lasting friendships among both German and foreign students, and, most important of all, completed the work necessary for the doctor's degree by midsummer of 1911. There remained the final examinations and the matter of publication of the thesis, but at this point the initial $1800 were exhausted and it became necessary to return to America and find a job.

At this critical juncture, his fellow-student and friend D. D. Van Slyke received a cable from his father, the chief chemist at the New York Agricultural Experiment Station in Geneva, New York, asking if there was anyone among the group in Fischer's laboratory who could be recommended for a position in the chemical laboratory at Geneva. As a result, Anderson arrived in Geneva in September with less than $50.00 in his pocket, without the coveted doctor's degree, and thoroughly discouraged. It was the beginning of his professional career as a research chemist, and was obviously a low point in his life. Even the project to which he was assigned was unattractive to him. He was to study the metabolism of dairy cows on a ration

deficient in phytin. His comment in later years on the situation was as follows:

"I knew nothing about cows except that they sometimes gave milk, I knew absolutely nothing about metabolism, and I had never heard of phytin. I asked the Director about phytin and what it was. He himself knew very little about phytin except that it was an organic phosphorus compound that occurred in wheat bran. He gave me some bulletins to read in which some earlier experiments were described, and these I studied with care.

"After due consideration of my situation and the work that I was asked to do, I had to admit to myself that I was utterly unprepared to undertake any metabolism studies on cows. As experimental subjects I considered cows most unpromising and depressing. I knew that it was often difficult enough to interpret a reaction correctly when tests were made in clean and transparent test tubes, but how could I or anyone else tell what happened when you fed a substance like phytin of unknown composition to a cow? . . . I decided that my salvation would have to lie in the chemistry of phytin. Since practically nothing was known concerning the chemistry and composition of this substance, it occurred to me that here was an opportunity to apply my training in organic chemistry in an attempt to solve the chemical constitution of this important plant constituent. With some hesitation I presented my program to the Director. I began by asking whether all seeds or grains contained the same phytin. No, he did not know. Then I suggested that, before undertaking long and expensive experiments with dairy cows, it would be desirable to know what phytin really was and whether the same phytin occurred in wheat, in oats, corn, or cottonseed-meal, since all of these products were used in the rations of dairy cows. He agreed that such a preliminary study was needed and I was authorized to proceed. By this means, then, I was able to side-track for an indefinite period the experiments with cows . . . and set to work on phytin with real enthusiasm."

Thus began the investigations of phytin that laid the foundation

of Anderson's reputation. In less than two years he had some eight published papers as evidence of his success; he then made shrewd use of an offer of a position in the Bureau of Chemistry in Washington to persuade the authorities at Geneva to give him a raise in salary and a year's leave of absence to go to Germany and complete the chemical investigation of phytin and obtain the doctor's degree. The early spring of 1914 thus found him again in Fischer's laboratory busily completing the work on phytin, and preparing himself for the final examinations. The political events of the summer of 1914, however, led to further frustration. He describes their immediate effect upon his prospects as follows:

"One day towards the end of July I had been working on some analyses until about three o'clock in the afternoon when I went out for a late lunch. On my way back to the laboratory, army automobiles passed and distributed extra editions of the newspapers. I picked up one of these papers and read the startling headlines—*Kriegsgefahrszustand*—that meant mobilization of the Army. I brought the sheet with me into the laboratory where it caused a scene of pandemonium.

"The German students crowded around me and, after reading the announcement, they swept their work benches clean of valuable apparatus and material on to the floor, after which they formed lines and marched out of the building, singing *'Deutschland über Alles.'* In less than 5 minutes the only persons remaining in the laboratory were the professors and a few foreign students."

A few weeks later, Anderson left Berlin on one of the trains provided through the efforts of Ambassador Gerard to take Americans stranded in Germany to Holland, and from there he made his way to England. Here he found it impossible to obtain transportation to America at a price he could afford, so, after a pleasant vacation period of a few weeks, he joined the group in Professor Ernest Henry Starling's laboratory at University College, London.

It happened that R. H. A. Plimmer had been working on the enzyme phytase, and that solutions remained from an experiment in

which commercial phytin had been treated with an extract of wheat bran. Anderson worked up these solutions and demonstrated that they contained inositol mono- and triphosphates identical with substances he had previously isolated. A renewed study of the enzyme followed which confirmed Plimmer's earlier results, although the report makes quaint reading today since the conception of pH had not yet found its way to Starling's laboratory. However, the work with the enzyme furnished the key to the explanation of the previouly incomprehensible results obtained with the preparations of phytin from wheat bran.

The earlier customary use of 0.2 per cent hydrochloric acid to extract the phosphorus compounds provided conditions under which phytase decomposed a considerable part of the phosphoric acid esters of inositol, with the result that the barium salts obtained were intractable mixtures. When 1 per cent acid was used, however, the activity of the enzyme was inhibited, and the extracts from wheat bran readily yielded inositol hexaphosphate identical with the products obtained at Geneva from corn, oats, cotton seed, and commercial phytin. It was present in the seeds as the calcium salt. The difficult problem of the nature of the phytin of wheat bran was thus solved.

Anderson returned to Geneva early in 1915 and resumed his work. His contact with the biochemists and physiologists in Starling's laboratory had broadened his interests, and for a few years he worked with animals. Inositol was shown to be largely excreted unused by the dog. In man, about 9 per cent is excreted in the urine, the rest being destroyed without appreciable effect on the metabolism. There was also a study of the volatile aromatic oils of animal urine which showed that cresol is the main component. In the spring of 1917 he spent several months in the laboratory of Professor Graham Lusk at Cornell Medical College learning the methods of animal calorimetry to be applied to a study of the nutrition of poultry at Geneva.

Shortly after the United States entered the war, Anderson volunteered and was commissioned a Captain in the Sanitary Corps in the

Division of Food and Nutrition. He was assigned inspection duties in various camps in the South and, later, was in charge of teaching officers within the Division. After the armistice, he was stationed at the debarkation camp in Hoboken and at Camp Merritt, New Jersey. He was discharged in January, 1919, but, before returning to Geneva, asked for leave to complete the requirements for the doctor's degree in Lusk's laboratory at the Cornell University Medical College. His work on phytin was promptly accepted as satisfying the requirements for a major in chemistry, and by the end of the academic year he had completed the necessary work on minors in physiology and bacteriology and obtained the degree for which he had striven so long. Shortly thereafter he married Clara Tillinghast of Englewood, New Jersey.

On his return to the laboratory at Geneva with an appointment as Chief Biochemist and the rank of Professor at Cornell University, Anderson gave a great deal of thought to the direction in which his future investigations should proceed. He was still interested in the biochemical studies begun with Lusk, and he devoted considerable time to an investigation of the dietary polyneuritis of poultry. The importance of grapes in the agriculture of upper New York State suggested that organic chemical work on the pigments of the fruit might be of help to the geneticists who were interested in improving the varieties grown. Accordingly, each fall for several years many kilograms of grape skins were collected and extracted with solvents. The outcome was a demonstration that the pigment of native American grapes, of which the Concord variety is an example, differs from the pigment of the chief European species. Furthermore, he established the constitution of the anthocyanidine oenidin of the European grape a year before this was accomplished by Paul Karrer in Switzerland, and also showed that in hybrids between American and European species the pigment of the European species predominates.

It should not be supposed that the grape residues from which the skins had been removed were allowed to go to waste. Anderson be-

came an amateur wine-maker of distinction. His champagne type and other wines have been enjoyed by most of his friends, and his cellar during the final years of prohibition was a source of astonishment and pleasure to the few who were allowed to see it.

Despite these other interests, the most attractive possibility for a future program of investigation appeared to be the study of the nucleic acids of plants, of which only two representatives were then known, the nucleic acid of yeast recently studied by P. A. Levene, and the triticonucleic acid of wheat embryo isolated some twenty years before by T. B. Osborne. The pollen of the corn plant was selected as a likely source of nucleic acid and large quantities were collected. Before the nucleic acid could be extracted with dilute alkali, it was found necessary to remove the fatty substances by extraction with alcohol and ether. The material in this extract amounted to about one-quarter of the weight of the pollen, and the extracts were accordingly carefully examined. The components were found to be mainly fats and sterols, and the sterols were particularly interesting, for they appeared to be substances new to chemistry.

The search for the nucleic acids of pollen was thereupon set aside, and a long series of investigations of the sterols present in the oils of plant seeds was undertaken. It was found that the substance described in the literature as sitosterol, and widely regarded as a pure and homogeneous sterol, is a mixture of at least five components. Two minor components were identified as stigmasterol, and a new substance characterized as dihydrositosterol or sitostanol. Sitostanol was demonstrated to be formed by catalytic reduction of purified sitosterol. Nevertheless the preparations of sitosterol even after purification were found to be a mixture of three components; of these only the γ-sitosterol was obtained in satisfactorily homogeneous condition. Subsequent investigation by others has shown that Anderson's α-sitosterol, which he stated was obviously a mixture, consists of at least three isomeric components.

The independent and simultaneous discovery in 1924 by A. F. Hess and H. L. Steenbock that the irradiation of foodstuffs with ultravio-

let light gives rise to the generation of vitamin D activity, and that it is the sterols in the foods which are responsible for this change, at once aroused widespread interest in plant sterols. Anderson was almost the only chemist in America at the time who had had extensive experience with these substances, and his work immediately attracted attention. He was invited to present a paper at the Symposium on Organic Chemistry held in Rochester in December, 1925. Professor T. B. Johnson of Yale University was in the audience, and it happened that he had recently been investigating the nucleic acids of the tubercle bacillus. The organism contains a great deal of fatlike material, and Dr. W. C. White of the Research Committee of the National Tuberculosis Association had urged Johnson to undertake the examination of the sterols associated with this fat. Accordingly, Johnson invited Anderson to come to Yale the following year and try to isolate the sterols of the tubercle bacillus.

Anderson began his work at Yale in October, 1926, for the first year under a Sterling Fellowship and subsequently as Professor of Chemistry, a post that he held until his retirement as Professor Emeritus in 1948. The investigations of the tubercle bacillus were supported by annual grants from the Committee on Medical Research of the National Tuberculosis Association, and a few parallel studies of other organisms by grants from the International Cancer Research Foundation and from the Leonard Wood Memorial. The tuberculosis bacilli were grown by H. K. Mulford and Company on the Long synthetic medium, and the preliminary treatment was carried out in their research laboratory, the washed organisms being taken to Yale in large bottles under a mixture of alcohol and ether.

The first task was to separate and fractionate the fatty components, the product from some two thousand culture bottles and representing nearly 4 kilograms of dry substance being worked up. The techniques developed in the course of previous studies of plant fats were used, and main fractions that represented phosphatides, acetone-soluble fat, and waxes were obtained, together with small fractions that represented water-soluble basic substances and carbohydrates.

The extracted residues were later treated with dilute alcoholic hydrochloric acid, and another substantial quantity of fat solvent-soluble material, mainly of waxlike nature, was thus liberated and subjected to examination. The fatty material accounted for nearly 24 per cent of the dry matter of the organisms, but in spite of the most careful examination, no trace of sterol-like substances was then or later found. The research thus became a study of the substances present in the fat solvent-soluble material of the organism rather than an investigation of sterols.

The first examination of the phosphatide fractions led to the discovery of a new fatty acid which, in the crude form, was a liquid, saturated, optically active substance. Shortly thereafter, a preparation of a similar material obtained from the acetone-soluble fat was shown to be a mixture, the chief components of which were a liquid saturated acid, isomeric with stearic acid, to which the name tuberculostearic acid was given, and a solid acid with a melting point of 28° and specific rotation of +8°, which was named phthioic acid. Its composition corresponded to the formula $C_{26}H_{52}O_2$ and it was accordingly an isomer of cerotic acid. This substance when injected into animals was found by Dr. Florence Sabin of the Rockefeller Institute, who cooperated in the investigation, to stimulate the proliferation of monocytes and epithelioid cells, and to bring about the formation of massive artificial tubercular tissue. The nature of the agent responsible for this important biological reaction was thus promptly established. The new acids were found in all of the main lipid fractions from the organism.

In addition to the study of human tuberculosis bacilli, examinations were made on the same large scale of the avian and the bovine strains of this organism, and of two other acid-fast bacteria, the nonpathogenic timothy grass bacillus and the leprosy bacillus. Although different in detail, all of these organisms were similar with respect to the general composition of the fatty substances they contained, and all were sources of new and interesting chemical substances. None contained sterols.

By 1932, it was possible to report that the phosphatides were low in nitrogen content and did not contain choline, but were high in palmitic acid and oleic acid as well as in the new kind of liquid saturated fatty acids. The water-soluble components of the phosphatides after hydrolysis contained mannose and inositol, apparently in combination as a polysaccharide, together with other sugars and glycerophosphoric acid. The acetone-soluble fat consisted of fatty acids, mainly palmitic, and the new type of liquid fatty acids, but the fat was not a glyceride. It appeared to be a complex ester of a carbohydratelike substance later identified as trehalose. The wax fraction could be separated into several subfractions, and from one of these the rare pentose D-arabinose was separated, together with mannose and galactose and a mixture of fatty acids which consisted mainly of palmitic and stearic acids. It also contained small amounts of organic phosphorus. A so-called soft wax fraction turned out to be a glyceride of fatty acids in which palmitic, stearic, and the new kind of liquid acids were detected, together with unsaturated fatty acids. In addition, there was an unsaponifiable wax from which normal hexacosanic acid was obtained in large yield by dry distillation.

With the broad principles established according to which the lipids of the acid-fast bacilli could be fractionated into groups of substances of presumably similar chemical characteristics, Anderson, with the help of a long succession of graduate students and postdoctoral fellows, proceeded with the detailed examination of the fractions from each of these organisms. From time to time other organisms were examined, especially the bacillus which produces crown gall on plants and the larvae of the tapeworm of the cat. These organisms were of special interest to the International Cancer Research Foundation because they are responsible for the stimulation of abnormal growth. *Bacillus acidophilus* and *Azotobacter chroococcum* were studied because of their interest to other members of the Yale faculty. Some of these organisms were found to contain sterols. In addition, yeast and the oil of the coffee bean were examined under grants made for the purpose by Standard Brands, Inc.

Phthioic acid, first found in the human tubercle bacillus in 1932, was shown in 1936 to contain a branched chain with a methyl group on the α-carbon and two other methyl groups of which one was probably on carbon atom 11. Anisic acid and the yellow pigment phthiocol were isolated in 1933. The pigment was a previously unknown substance, which was shown by synthesis to be 2-methyl-3-hydroxy-1,4-naphthaquinone. In 1934, tuberculostearic acid was shown to be 10-methylstearic acid. The phosphatide was found in 1938 to contain a substance named manninositose, which was shown to be a polysaccharide consisting of two molecules of mannose and one of inositol. The phosphatide was present in the organism as an ester of a number of fatty acids on a phosphorylated derivative of this substance.

Two new alcohols, *d*-2-eicosanol and *d*-2-octadecanol were isolated in 1936 from the unsaponifiable matter derived from the wax of the timothy grass bacillus, and also from the similar fractions obtained from the leprosy bacillus and the avian tubercle bacillus. In the human strain, however, these alcohols were replaced by a new substance designated phthiocerol, an optically active alcohol with the formula $C_{36}H_{74}O_3$ which contained two hydroxyl groups and one methoxyl group.

The hard waxes of these organisms were studied with special care. A substance named mycolic acid with the formula $C_{88}H_{176}O_4$ and containing one hydroxyl, one carboxyl, and one methoxyl group was found in the wax of the human strain in 1938. It amounted to about 56 per cent of the wax. Its most characteristic property was that on pyrolytic distillation in a vacuum, it yielded about 22 per cent of pure normal hexacosanic acid. Mycolic acid also exhibited the property of "acid-fastness" when tested by the usual bacteriological technique. It was the only substance found in the organism that behaved in this way, and is doubtless the material that accounts for this property in the intact organism. Two mycolic acids slightly different from that of the human strain were found in the avian strain. One gave a branched-chain pentacosanic acid on dry distillation in a vacuum

while the other gave normal tetracosanic acid. The timothy grass bacillus also contained an analogous substance, which likewise yielded tetracosanic acid on distillation.

Among the components of the wax was found a levorotatory fatty acid of the formula $C_{30}H_{60}O_2$, which was given the name mycocerosic acid. This occurred along with such usual components as palmitic acid, together with tuberculostearic acid and dextrorotatory fatty acids analogous to phthioic acid. These acids were combined with a carbohydrate which yielded pentoses and hexoses on hydrolysis.

In addition to the lipids that are extracted by treating the organisms with a mixture of alcohol and ether and subsequently with chloroform, all of these acid-fast bacilli contained lipids in a tightly bound form. These could be liberated only by treating the previously extracted cells with acidified alcohol–ether mixtures. Material of this kind from the human strain contained a large proportion of a hydroxy acid of high molecular weight, similar to a substance found in the purified wax, together with smaller proportions of the ordinary fatty acids, among which tuberculostearic acid was found. These acids were combined in the crude lipid with a complex carbohydrate. Analogous materials were found in the other strains of the organism.

Shortly before he retired, Anderson had an exhibit prepared of the numerous substances that had resulted from these investigations. They were arranged so as to show the origin of each pure product from the fractions of crude lipid obtained from the various organisms. The exhibit, numbering some three hundred sealed tubes, stands in the main corridor of the Sterling Chemical Laboratory at Yale, where it attracts the attention of every student. At the time this exhibit was presented to the University, Anderson explained the preparations as follows:

"Many of the cleavage products, both fatty acids and carbohydrates, are identical with substances found both in plants and animals, but in the compounds isolated from the tubercle bacillus they are combined in an entirely different manner from that found in the usual plant or animal kingdom. It will suffice to mention just a few of

these peculiarities. For instance, all ordinary fats are glycerides, that is, fatty acid esters of glycerol. The fat of the tubercle bacillus does not contain any glycerol, but represents fatty acid esters of the disaccharide trehalose. The phosphatides of plants and animals are compounds containing glycerophosphoric acid combined with fatty acids and a nitrogenous base which is either choline or aminoethyl alcohol. The phosphatide of the tubercle bacillus also contains glycerophosphoric acid and fatty acids, but it does not contain any nitrogen base. Instead it contains a polysaccharide which on hydrolysis yields inositol, mannose, and glucose. The waxes found in plant and animal products are fatty acid esters of higher alcohols. The tubercle bacillus contains a high percentage of a material which in its crude state very closely resembles an ordinary wax. However, when this material is purified and analyzed it is found to consist of a combination of a specific polysaccharide with mycolic acid, together with certain levorotatory acids and the specific alcohol phthiocerol. It is evident, therefore, that substances contained in the tubercle bacillus such as fats, phosphatides, and waxes differ entirely in composition and structure from previously known analogous compounds."

This exhibit is described by H. G. Cassidy in the *Journal of Chemical Education,* 36:228 (1959).

Anderson's work is characterized by the patience and skill with which he purified the materials with which he was dealing. As he records himself, at the beginning of each of the projects he undertook, the studies on brucine in Germany, the work on phytin and on sterols at Geneva, and on the lipids of acid-fast bacilli at Yale, he was completely ignorant of the background of the subject at the start and, with the possible exception of the work on brucine, found that the literature of the subject was confused, inaccurate, and of little help. It was necessary for him to develop novel techniques in each instance, and to follow each stage of the isolation with the most rigid control by analytical methods. His personal skill as an analyst, and his sound knowledge of fundamental organic chemistry carried him through to success. There were no easy short-cut chromatographic

methods available at the time to serve as controls or as evidence of purity, and it was only in the later years at Yale that microanalytical methods became available. Earlier, he was frequently compelled to use most of a valuable preparation for the analysis required to demonstrate its identity, and a long series of laborious operations was required to obtain more of it.

The initial stocks of bacilli of several kinds prepared by the Mulford Company served for many years as the material for investigation, although, later, by-products from the production of tuberculin were also studied, as well as a few cultures of strains of the human bacillus other than the one originally employed. Moderate differences in composition were detected, but the main principles established with the original culture were never called in question. The work was fundamentally sound and extremely thorough, and has been of the greatest assistance to all students of tuberculosis. It is the classic study of its kind and is referred to in all textbooks and reviews of the subject.

Anderson's chemical investigations of the lipids of acid-fast bacilli are internationally known, but American biochemists are probably most familiar with him in his capacity as managing editor of the *Journal of Biological Chemistry,* a position that he held from 1937 until 1958. His responsibilities began with volume 118. The circulation of the journal at the time of his retirement with the publication of volume 232 had increased nearly fourfold, and the number of pages printed annually had nearly doubled. Under his kindly but firm administration, it became the leading publication in its field in the world.

The editorial office occupied two floors at the top of one of Yale's many towers, the space being provided rent-free by the University. Here Anderson examined each manuscript as it came in and briefly noted faults and deficiencies, if any. The manuscript was then sent to a member of his editorial board for detailed study and, if necessary, for submission to referees. When the combined reports were received, suggestions for improvements and criticisms, if any, were

assembled into an impersonal but invariable kindly editorial letter, and manuscript and letter were returned to the author for his further action. No manuscript was ever rejected until Anderson had himself read it with care to see if some nugget of wisdom or scientific discovery could be saved. The decision for rejection required the independent advice of at least two members of the board.

On acceptance, a manuscript was turned over to his skilled staff who corrected grammar, removed solecisms and jargon, brought the text into conformity with journal style, checked the bibliography, and prepared the whole for the printer. Debatable points were referred to Anderson for decision. Later, the author had the opportunity to read both galley and page proof, although galleys were also proof read by the staff. To the writer's knowledge, no manuscript ever survived this process unchanged in some detail. Although perfection was probably rarely attained, no effort was spared to approach it. The work required untold hours away from the laboratory and filled many of Anderson's evenings. It was a service to biochemistry of the utmost importance.

Anderson was accustomed each year to entertain the members of his editorial board at a dinner during the meetings of the American Society of Biological Chemists. None who were so fortunate as to attend these functions will ever forget the carefully chosen menus prepared after personal consultation with the hotel chef, the excellent wines and cigars, and the extraordinary feeling of good-fellowship and of affection for their host.

On the more practical side, Anderson so conducted the affairs of the journal that, in spite of rising prices and increasing demands upon space, an annual profit was usually declared. He was solely responsible for all income and expenditure, a most unusual arrangement, and on his retirement was able to turn over to the financial officers of the Society a sum of money sufficient to insure the future of the journal for many years.

Anderson was elected president of the American Society of Biological Chemists in 1941, and to membership in the National Acad-

emy of Sciences in 1946. The same year he became a member of the Connecticut Academy of Sciences and in 1947 was awarded the honorary degree of M.D. by the University of Lund. He received the Trudeau medal of the National Tuberculosis Association in 1948 and was made an honorary member of the Connecticut Medical Society in 1951. He served Yale University for many years as a member of the Board of Scientific Advisors of the Jane Coffin Childs Foundation. He was a Fellow of Calhoun College and served on numerous faculty committees. In 1958, on his retirement as managing editor, the December number of the *Journal of Biological Chemistry* was dedicated to him. It contained his picture, and papers contributed in his honor by his associates on the successive Editorial Boards and Editorial Committees who had served under him. A specially bound copy was presented to him at a meeting held for the purpose in New Haven.

He was a member of several social clubs in New Haven, and in Guilford, Connecticut, where he had purchased for a summer home an old Connecticut farmhouse that he and Mrs. Anderson had restored and furnished with antiques. There they spent many week ends and vacations working in the garden and entertaining numerous friends.

Anderson will be remembered as a tall, impressive, and forceful personality of great dignity, and charming, but somewhat formal manners. To his close friends, he revealed a fine sense of humor, a vast although specialized knowledge of organic chemistry, and a fundamental kindness and simplicity that won him instant affection. Both in his scientific work and in his administration of the complex financial affairs of the journal, his integrity was unquestioned. He was an ornament to American biochemistry whose services both as investigator and editor will long be remembered.

In 1943 he wrote this tribute to the country of his adoption:

"I feel convinced that a career such as I have experienced could have been possible only in America where opportunity for education and advancement has been available for everyone who was willing

to work. Even foreign born persons like myself were given the same opportunities to work out their own destinies and salvation that were the right of the native born citizens."

For most of the information concerning Anderson's early life and education, I am indebted to Mrs. Anderson who kindly made available the autobiographical document written in 1943 in which he so amusingly describes his experiences, and from which I have liberally quoted. The file also contained a copy of his essay presented to Tulane University in 1906. In addition, in 1959 he left with me a copy of another document entitled "An Account of the Chemical Training and Scientific Work of Rudolph J. Anderson," in which a great deal of additional detail regarding his early life was given, together with a short account of the work at Yale on acid-fast bacilli. I have also had the use of a brief statement he filed with the Home Secretary of the Academy.

KEY TO ABBREVIATIONS

Am. J. Physiol.=American Journal of Physiology
Am. Rev. Tuberculosis=American Review of Tuberculosis
Ann. Rev. Biochem.=Annual Review of Biochemistry
Ber. deut. chem. Gesell.=Berichte der deutschen chemischen Gesellschaft
Chem. Rev.=Chemical Reviews
J. Am. Chem. Soc.=Journal of the American Chemical Society
J. Biol. Chem.=Journal of Biological Chemistry
Physiol. Rev.=Physiological Reviews
Proc. Nat. Acad. Sci.=Proceedings of the National Academy of Sciences
Proc. Soc. Exp. Biol. Med.=Proceedings of Society of Experimental Biology and Medicine
Pub. Am. Assoc. Adv. Sci.=Publication of the American Association for the Advancement of Science
Sigma Xi Quart.=Sigma Xi Quarterly
Yale J. Biol. Med.=Yale Journal of Biology and Medicine
Z. physiol. Chem.=Zeitschrift für physiologische Chemie

BIBLIOGRAPHY

This bibiography is mainly a copy of a list of publications prepared by Anderson for the files of the Department of Chemistry at Yale. I am indebted to Professor Julian Sturtevant for its use. The list has been completed from the indexes of *Chemical Abstracts*. Omitted from the list are references to Technical Bulletins published by the New York Agricultural Experiment Station at Geneva in which parallel publication of the work on phytin and on sterols was made. Also omitted are a number of references to abstracts of papers presented at meetings of the American Society of Biological Chemists. These abstracts were printed in the Proceedings.

1911

With Hermann Leuchs. Zur Kenntnis der Brucin-Salpetersäure-Reaktion und über die Darstellung eines neuen Alkaloids, des Bis-apomethyl-Brucins. Ber. deut. chem. Gesell., 44:2136.

With Hermann Leuchs. Über Derivate des Bisapomethyl-Brucins. Ber. deut. chem. Gesell., 44:3040.

1912

Phytin and Phosphoric Acid Esters of Inosite. J. Biol. Chem., 11:471.

Phytin II. Phytin and Pyrophosphoric Acid Esters of Inosite. J. Biol. Chem., 12:97.

Phytin III. Concerning the Organic Phosphoric Acid Compound of Wheat Bran. J. Biol. Chem., 12:447.

The Organic Phosphoric Acid of Cottonseed Meal. J. Biol. Chem., 13:311.

1914

Phytin V. Concerning the Organic Phosphoric Acid of Cottonseed Meal. II. J. Biol. Chem., 17:141.

Phytin VI. Concerning Phytin in Oats. J. Biol. Chem., 17:151.

Phytin VII. Concerning Phytin in Corn. J. Biol. Chem., 17:165.

Phytin VIII. A Contribution to the Chemistry of Phytin. I. Composition of Barium Phytate and Phytic Acid. II. A Study of the Properties of Phytic Acid and Its Decomposition Products. J. Biol. Chem., 17:171.

Phytin IX. Concerning the Organic Phosphoric Acid Compound of Wheat Bran. II. J. Biol. Chem., 18:425.

Phytin X. Concerning the Organic Phosphoric Acid Compound of Wheat Bran. III. Inosite Monophosphate, a New Organic Phosphoric Acid Occurring in Wheat Bran. J. Biol. Chem., 18:441.

1915

Phytin XI. Concerning the Organic Phosphoric Acid Compound of Wheat Bran. IV. The Occurrence of Inosite Triphosphate in Wheat Bran. J. Biol. Chem., 20:463.

Phytin XII. The Hydrolysis of Phytin by the Enzyme Phytase Contained in Wheat Bran. J. Biol. Chem., 20:475.

Phytin XIII. The Hydrolysis of the Organic Phosphorus Compound of Wheat Bran by the Enzyme Phytase. J. Biol. Chem., 20:483.

Phytin XIV. Concerning Phytin in Wheat Bran. J. Biol. Chem., 20:493.

1916

The Utilization of Inosite in the Dog. J. Biol. Chem., 25:391.

With A. W. Bosworth. The Utilization of Inosite in the Animal Organism. The Effect of Inosite upon the Metabolism of Man. J. Biol. Chem., 25:399.

Concerning Certain Aromatic Constituents of Urine. I. The Non-phenolic Volatile Oils of Cow Urine. J. Biol. Chem., 26:387.

Concerning Certain Aromatic Constituents of Urine. II. The Non-phenolic Volatile Oils of Goat Urine. J. Biol. Chem., 26:401.

Concerning Certain Aromatic Constituents of Urine. III. The Non-phenolic Volatile Oils of Horse and Human Urine. J. Biol. Chem., 26: 409.

With Graham Lusk. The Interrelation between Diet and Body Condition and the Energy Production during Mechanical Work in the Dog. Proc. Nat. Acad. Sci., 3:386.

1917

With Graham Lusk. Animal Calorimetry. The Interrelation between Diet and Body Condition and the Energy Production during Mechanical Work. J. Biol. Chem., 32:421.

1918

A Note on the Analysis and Composition of the Seed of the Silver Maple (*Acer saccharinum*). J. Biol. Chem., 34:509.

1919

The Practicability of Feeding a Scientifically Balanced Ration in Army Camps. Am. J. Physiol., 49:523.

The Occurrence of Organic Phosphorus Compounds in Plants. Ph.D. Thesis, Columbia University.

1920

Phytin XV. Synthesis of Phytic Acid. J. Biol. Chem., 43:117.

With collaboration of W. L. Kulp. Phytin XVI. Occurrence of Inosite Hexaphosphoric Acid in the Seed of the Silver Maple (*Acer saccharinum*). J. Biol. Chem., 43:469.

Phytin XVII. Composition of Inosite Phosphoric Acid of Plants. J. Biol. Chem., 44:429–38.

With collaboration of W. L. Kulp. Acerin: The Globulin of Maple Seed (*Acer saccharinum*). J. Biol. Chem. (Proc.), 46:xxxvi.

1921

With collaboration of W. L. Kulp. Acerin. The Globulin of the Maple Seed (*Acer saccharinum*). J. Biol. Chem., 48:23.

1922

With W. L. Kulp. Analysis and Composition of Corn Pollen. Preliminary Report. J. Biol. Chem., 50:433.

With W. L. Kulp. A Study of the Metabolism and Respiratory Exchange in Poultry during Vitamine Starvation and Polyneuritis. J. Biol. Chem., 52:69.

1923

Composition of Corn Pollen. II. Concerning Certain Lipoids, a Hydrocarbon, and Phytosterol Occurring in the Pollen of White Flint Corn. J. Biol. Chem., 55:611.

Concerning the Anthocyans in Norton and Concord Grapes. A Contribution to the Chemistry of Grape Pigments. J. Biol. Chem., 57:795.

With M. G. Moore. A Study of the Phytosterols of Corn Oil, Cottonseed Oil, and Linseed Oil. J. Am. Chem. Soc., 45:1944.

1924

With F. P. Nabenhauer. A Contribution to the Chemistry of Grape Pigments. II. Concerning the Anthocyans in Clinton Grapes. J. Biol. Chem., 61:97.

A Contribution to the Chemistry of Grape Pigments. III. Concerning the Anthocyans in Seibel Grapes. J. Biol. Chem., 61:685.

The Phytosterols of the Endosperm of Corn. J. Am. Chem. Soc., 46:1450.

With F. P. Nabenhauer. The Phytosterols of Wheat Endosperm. J. Am. Chem. Soc., 46:1717.

With F. P. Nabenhauer. The Separation of Unsaturated from Saturated Sterols. J. Am. Chem. Soc., 46:1957.

With F. P. Nabenhauer. Sitosterol. J. Am. Chem. Soc., 46:2113.

With F. P. Nabenhauer. Reduction of Sitosterol. Preparation of Dihydrositosterol or Sitostanol. J. Am. Chem. Soc., 46:1953.

1926

With F. P. Nabenhauer. The Phytosterols of Rice Bran Fat. J. Am. Chem. Soc., 48:2972.

With R. L. Shriner. The Phytosterols of Corn Oil. J. Am. Chem. Soc., 48:2976.

With R. L. Shriner and G. O. Burr. The Phytosterols of Wheat Germ Oil. J. Am. Chem. Soc., 48:2987.

With F. P. Nabenhauer. A Contribution to the Chemistry of Grape Pigments. IV. The Anthocyans in Isabella Grapes. J. Am. Chem. Soc., 48: 2997.

With F. P. Nabenhauer and R. L. Shriner. The Distribution of Dihydrositosterol in Plant Fats. Proc. Soc. Exp. Biol. Med., 24:63.

1927

With F. P. Nabenhauer and R. L. Shriner. The Distribution of Dihydrositosterol in Plant Fats. J. Biol. Chem., 71:389.

With R. L. Shriner. The Reduction Products of Certain Plant Sterols. J. Biol. Chem., 71:401.

Properties of Cholesterol Obtained from Different Sources. J. Biol. Chem., 71:407.

With R. L. Shriner and F. P. Nabenhauer. The Composition of Corn Wax. J. Am. Chem. Soc., 49:1290.

With A. E. Hess. The Antirachitic Value of Irradiated Cholesterol and Phytosterol. VIII. The Activation of Sterol Fractions by Ultraviolet Irradiation. J. Biol. Chem., 74:651.

The Separation of Lipoid Fractions from Tubercle Bacilli. J. Biol. Chem., 74:525.

A Study of the Phosphatide Fraction of Tubercle Bacilli. J. Biol. Chem., 74:537.

1928

With R. L. Shriner. A Contribution to the Chemistry of Grape Pigments. V. The Anthocyans in Ives Grapes. J. Biol. Chem., 80:743.

1929

The Chemistry of the Lipoids of Tubercle Bacilli. III. Concerning Phthioic Acid. Preparation and Properties of Phthioic Acid. J. Biol. Chem., 83:169.

The Chemistry of the Lipoids of Tubercle Bacilli. IV. Concerning the So-called Tubercle Bacilli Wax. Analysis of the Purified Wax. J. Biol. Chem.: 83:505.

The Chemistry of the Lipoids of Tubercle Bacilli. V. Analysis of the Acetone-soluble Fat. J. Biol. Chem., 84:703.

With E. Chargaff. The Chemistry of the Lipoids of Tubercle Bacilli. VI. Concerning Tuberculostearic Acid and Phthioic Acid from the Acetone-soluble Fat. J. Biol. Chem., 85:77.

Chemical Investigations of Biologically Active Lipoids of Tubercle Bacilli. Proc. Nat. Acad. Sci., 15:628.

The Chemistry of the Lipoids of Tubercle Bacilli. VII. Analysis of the Soft Wax from Tubercle Bacilli. J. Biol. Chem., 85:327.

The Chemistry of the Lipoids of Tubercle Bacilli. VIII. Concerning the Unsaponifiable Wax. J. Biol. Chem., 85:339.

The Chemistry of the Lipoids of Tubercle Bacilli. IX. The Occurrence of Hexacosanic Acid in the Unsaponifiable Wax. J. Biol. Chem., 85:351.

1930

With E. G. Roberts. The Chemistry of the Lipoids of Tubercle Bacilli. X. The Separation of Lipoid Fractions from Avian Tubercle Bacilli. J. Biol. Chem., 85:509–17.

With E. G. Roberts. The Chemistry of the Lipoids of Tubercle Bacilli. XI. The Phosphatide Fraction of the Avian Tubercle Bacilli. J. Biol. Chem., 85:519–28.

With E. G. Roberts. The Chemistry of the Lipoids of Tubercle Bacilli. XII. The Separation of the Lipoid Fractions from Bovine Tubercle Bacilli. J. Biol. Chem., 85:529–38.

With A. G. Renfrew. The Chemistry of the Lipoids of Tubercle Bacilli. XIII. The Occurrence of Mannose in the Phosphatide from Human Tubercle Bacilli. J. Am. Chem. Soc., 52:1252.

The Chemistry of the Lipoids of Tubercle Bacilli. XIV. The Occurrence of Inosite in the Phosphatide from Human Tubercle Bacilli. J. Am. Chem. Soc., 52:1607.

With E. G. Roberts and A. G. Renfrew. The Chemistry of the Lipoids of Tubercle Bacilli. XV. Water-soluble Sugars Obtained on Hydrolyzing Phosphatides from Human and Avian Tubercle Bacilli. Proc. Soc. Exp. Biol. Med., 27:387.

With E. Chargaff. Über die Zusammensetzung des gesamten extrahierbaren Fettes der Tuberkelbakterien. Z. physiol. Chem., 191:157.

With E. Chargaff. Über das Vorkommen einer ungesättigten Hexakosansäure im Fett der Tuberkelbakterien. Z. physiol. Chem., 191:166.

With E. Chargaff. Ein Polysaccharid aus den Lipoiden der Tuberkelbakterien. Z. physiol. Chem., 191:172.

With E. G. Roberts. Concerning the Carbohydrates Associated with the Ether-soluble Lipoids of Tubercle Bacilli. Am. Rev. Tuberculosis, 22: 664.

With E. G. Roberts. The Chemistry of the Lipoids of Tubercle Bacilli. XIX. Concerning the Composition of the Phosphatide Fraction Isolated from the Bovine Type of Tubercle Bacilli. J. Biol. Chem., 89:599.

With E. G. Roberts. The Chemistry of the Lipoids of Tubercle Bacilli. XX. The Occurrence of Mannose and Inosite in the Phosphatide Fractions from the Human, Avian, and Bovine Tubercle Bacilli. J. Biol. Chem., 89:611.

With E. G. Roberts. The Chemistry of the Lipoids of Tubercle Bacilli.

XXI. The Polysaccharide Occurring in the Phosphatide from the Human Tubercle Bacilli. J. Am. Chem. Soc., 52:5023.

1931

With E. G. Roberts. The Chemistry of the Lipoids of Tubercle Bacilli. XXII. Concerning the Carbohydrates of the Purified Wax. J. Biol. Chem., 90:33.

With E. Chargaff and M. C. Pangborn The Chemistry of the Lipoids of Tubercle Bacilli. XXIII. Separation of the Lipoid Fractions from the Timothy Bacillus. J. Biol. Chem., 90:45.

With M. L. Burt. The Chemistry of the Lipoids of Tubercle Bacilli. XXIV. Analysis of the Acetone-soluble Fat of the Bovine Tubercle Bacilli. J. Biol. Chem., 94:451.

With M. C. Pangborn. The Chemistry of the Lipoids of Tubercle Bacilli. XXV. The Composition of the Phosphatide Fraction of the Timothy Bacillus. J. Biol. Chem., 94:465.

A Discussion of Certain Fat Constituents of Acid-fast Bacteria. Am. Rev. Tuberculosis, 24:746.

1932

With N. Uyei. The Chemistry of the Lipoids of Tubercle Bacilli. XXVI. Separation of the Lipoid Fractions from the Leprosy Bacillus. J. Biol. Chem., 95:653.

The Chemistry of the Lipoids of Tubercle Bacilli. Physiol. Rev., 12:166.

The Chemistry of the Acyclic Constituents of Natural Fats and Oils. Ann. Rev. Biochem., 1:89.

With R. O. Bengis. The Chemistry of the Coffee Bean. I. Concerning the Unsaponifiable Matter of the Coffee Bean Oil. Preparation and Properties of Kahweol. J. Biol. Chem., 97:99.

With J. A. Crowder. A Contribution to the Chemistry of *Lactobacillus Acidophilus*. I. The Occurrence of Free, Optically Active, Dihydroxystearic Acid in the Fat Extracted from *Lactobacillus Acidophilus*. J. Biol. Chem., 97:393.

With N. Uyei. The Chemistry of the Lipids of Tubercle Bacilli. XXVII. The Composition of the Phosphatide Fraction of the *Bacillus leprae*. J. Biol. Chem., 97:617.

The Chemistry of the Lipids of Tubercle Bacilli. XXVIII. Studies on Phthioic Acid. Isolation of a Levorotatory Acid from the Phthioic Acid Fraction of the Human Tubercle Bacillus. J. Biol. Chem., 97:639.

With H. du Mont. Über Polysaccharide in Tuberkelbazillen. XXIX.

Abhandlung über die Lipoide der Tuberkelbazillen. Z. physiol. Chem., 211:97.

With St. Ludewig. Über Polysaccharide in Tuberkelbazillen. XXX. Abhandlung über die Lipoide der Tuberkelbakterien. Z. physiol. Chem., 211:103.

With M. C. Pangborn and E. Chargaff. The Chemistry of the Lipids of Tubercle Bacilli. XXXI. The Composition of the Acetone-soluble Fat of the Timothy Bacillus. J. Biol. Chem., 98:43.

1933

With M. C. Pangborn. The Chemistry of the Lipids of Tubercle Bacilli. XXXII. Isolation of Trehalose from the Timothy-grass Bacillus. J. Biol. Chem., 101:105.

With M. S. Newman. The Chemistry of the Lipids of Tubercle Bacilli. XXXIII. Isolation of Trehalose from the Acetone-soluble Fat of the Human Tubercle Bacillus. J. Biol. Chem., 101:499.

With M. S. Newman. The Chemistry of the Lipids of Tubercle Bacilli. XXXIV. Isolation of a Pigment and of Anisic Acid from the Acetone-soluble Fat of the Human Tubercle Bacillus. J. Biol. Chem., 101:773.

With M. S. Newman. The Chemistry of the Lipids of Tubercle Bacilli. XXXV. The Constitution of Phthiocol, the Pigment Isolated from the Human Tubercle Bacillus. J. Biol. Chem., 103:197.

With M. S. Newman. Über die Polysaccharide der Leprabazillen. Z. physiol. Chem., 220:1.

With M. S. Newman. The Chemistry of the Lipids of Tubercle Bacilli. XXXVII. The Synthesis of Phthiocol, the Pigment of the Human Tubercle Bacillus. J. Biol. Chem., 103:405.

With M. S. Newman. The Chemistry of the Lipids of Yeast. I. The Composition of the Acetone-soluble Fat. J. Biol. Chem., 102:219.

With M. S. Newman. The Chemistry of the Lipids of Yeast. II. The Composition of the Phospholipids. J. Biol. Chem., 102:229.

1934

With J. A. Crowder. A Contribution to the Chemistry of *Lactobacillus acidophilus*. II. Composition of the Neutral Fat. J. Biol. Chem., 104:399.

With J. A. Crowder. A Contribution to the Chemistry of *Lactobacillus acidophilus*. III. The Composition of the Phosphatide Fraction. J. Biol. Chem., 104: 487.

With R. O. Bengis. The Chemistry of the Coffee Bean. II. The Composition of the Glycerides of the Coffee Bean Oil. J. Biol. Chem., 105:139.

The Chemistry of the Acyclic Constituents of Natural Fats and Oils. Ann. Rev. Biochem., 3:59.

With M. S. Newman and J. A. Crowder. The Chemistry of the Lipids of Tubercle Bacilli. XXXVIII. A New Synthesis of Phthiocol, the Pigment of the Human Tubercle Bacillus. J. Biol. Chem., 105:279.

With M. A. Spielman. The Chemistry of the Lipids of Tubercle Bacilli. XXXIX. The Constitution of Tuberculostearic Acid. J. Biol. Chem., 106:87.

1935

With R. Schoenheimer, J. A. Crowder, and F. H. Stodola. Die Chemie der Tuberkelbazillen-Lipoide. XL. Über das Vorkommen von Sterinen in Tuberkelbazillen. Z. physiol. Chem., 237:40.

1936

With R. H. Sifferd. Über das Vorkommen von Sterinen in Bakterien. Z. physiol. Chem., 239:270.

With L. F. Salisbury. The Chemistry of the Lipids of Yeast. III. Lecithin and Cephalin. J. Biol. Chem., 112:541.

With M. C. Pangborn. The Chemistry of the Lipids of Tubercle Bacilli. XLI. Part 1. The Composition of the Timothy Bacillus Wax. Part 2. The Isolation of *d*-Eicosanol-2 and *d*-Octadecanol-2 from the Unsaponifiable Matter of the Timothy Bacillus Wax. J. Am. Chem. Soc., 58:10.

With M. A. Spielman. The Chemistry of the Lipids of Tubercle Bacilli. XLII. Studies on Phthioic Acid. J. Biol. Chem., 112:759.

With J. A. Crowder, M. S. Newman, and F. H. Stodola. The Chemistry of the Lipids of Tubercle Bacilli. XLIII. The Composition of Leprosin. J. Biol. Chem., 113:637.

With J. A. Crowder, F. H. Stodola, and M. C. Pangborn. The Chemistry of the Lipids of Tubercle Bacilli. XLIV. Comparative Study of the Lipids of the Human Tubercle Bacillus. J. Am. Chem. Soc., 58:636.

With J. A. Crowder and F. H. Stodola. The Chemistry of the Lipids of Tubercle Bacilli. XLV. Isolation of α- and β-Leprosol. J. Biol. Chem., 114:431.

With F. H. Stodola. The Chemistry of the Lipids of Tubercle Bacilli. XLVI. Phthiocerol, A New Alcohol from the Wax of the Human Tubercle Bacillus. J. Biol. Chem., 114:467.

1937

With R. E. Reeves. The Chemistry of the Lipids of Tubercle Bacilli.

XLVII. The Composition of the Avian Tubercle Bacillus Wax. J. Am. Chem. Soc., 59:858.

With R. E. Reeves. The Chemistry of the Lipids of Tubercle Bacilli. XLVIII. The Occurrence of Phthiocerol in the Wax from Various Strains of the Human Tubercle Bacillus. J. Biol. Chem., 119:535.

With R. E. Reeves. The Chemistry of the Lipids of Tubercle Bacilli. XLIX. The Colorimetric Determination of Phthiocol. J. Biol. Chem., 119:543.

With J. Cason. The Chemistry of the Lipids of Tubercle Bacilli. L. The Occurrence of Phthiocerol in the Wax of the Bovine Tubercle Bacilli. J. Biol. Chem., 119:549.

With R. E. Reeves and F. H. Stodola. The Chemistry of the Lipids of Tubercle Bacilli. LI. Concerning the Firmly Bound Lipids of the Human Tubercle Bacillus. J. Biol. Chem., 121:649.

With R. E. Reeves and J. A. Crowder. The Chemistry of the Lipids of Tubercle Bacilli. LII. The Composition of the Acetone-soluble Fat of *Bacillus leprae*. J. Biol. Chem., 121:669.

1938

With W. C. Lothrop and M. M. Creighton. The Chemistry of the Lipids of Tubercle Bacilli. LIII. Studies on the Phosphatide of the Human Tubercle Bacillus. J. Biol. Chem., 125:299.

With F. H. Stodola and A. Lesuk. The Chemistry of the Lipids of Tubercle Bacilli. LIV. The Isolation and Properties of Mycolic Acid. J. Biol. Chem., 126:505.

With C. W. Wieghard. The Chemistry of the Lipids of Tubercle Bacilli. LV. Studies on the Wax Fractions of the Human Tubercle Bacillus. J. Biol. Chem., 126:515.

With J. Cason. The Chemistry of the Lipids of Tubercle Bacilli. LVI. The Wax of the Bovine Tubercle Bacillus. J. Biol. Chem., 126:527.

1939

The Chemistry of the Tubercle Bacillus and Related Acid-fast Bacteria. A Review. Sigma Xi Quart., 27:39.

With L. F. Salisbury. The Chemistry of the Acyclic Constituents of Natural Fats and Oils. Ann. Rev. Biochem. 8:133.

Chemical Studies on the Tubercle Bacillus and Other Acid-fast Bacilli. Part I. Symposium Series, Pub. Am. Assoc. Adv. Sci., 1:20.

With M. M. Creighton. The Chemistry of the Lipids of Tubercle Bacilli.

LVII. The Mycolic Acids of the Avian Tubercle Bacillus Wax.. J. Biol. Chem., 129:57.

With W. B. Geiger, Jr., The Chemistry of *Phytomonas tumefaciens*. I. The Lipids of *Phytomonas tumefaciens*. The Composition of the Phosphatide. J. Biol. Chem., 129:519.

With L. F. Salisbury. Concerning the Chemical Composition of *Cysticercus fasciolaris*. J. Biol. Chem., 129:505.

With W. B. Geiger, Jr. The Chemistry of the Lipids of Tubercle Bacilli. LVIII. Concerning the Firmly Bound Lipids of the So Called Leprosy Bacillus. J. Biol. Chem., 131:539.

The Chemistry of the Lipids of Tubercle Bacilli. The Harvey Lectures, ser. 35, 1939–1940, pp. 271–313.

With M. M. Creighton. Concerning the Synthesis of Phthiocol. J. Biol. Chem., 130:429.

With M. M. Creighton. The Chemistry of the Lipids of Tubercle Bacilli. LIX. The Composition of the Polysaccharide of the Firmly Bound Lipids of the Leprosy Bacillus. J. Biol. Chem., 131:549.

1940

With M. M. Creighton and R. L. Peck. The Chemistry of the Lipids of Tubercle Bacilli. LX. Concerning the Firmly Bound Lipids of the Avian Tubercle Bacillus. J. Biol. Chem., 133:675.

With R. L. Peck and M. M. Creighton. The Chemistry of the Lipids of Tubercle Bacilli. LXI. The Polysaccharide of the Phosphatide Obtained from Cell Residues in the Preparation of Tuberculin. J. Biol. Chem., 136:211.

With A. Lesuk. The Chemistry of the Lipids of Tubercle Bacilli. LXII. Studies on Mycolic Acid. J. Biol. Chem., 136:603.

1941

Structural Pecularities of Acid-fast Bacterial Lipids. Chem. Rev., 29:225.

With A. Lesuk. Concerning the Chemical Composition of *Cysticercus fasciolaris*. II. The Occurrence of a Cerebroside Containing Dihydrosphingosine and of Hydrolecithin in *Cysticercus* Larvae. J. Biol. Chem., 139:457.

With R. L. Peck. The Chemistry of the Lipids of Tubercle Bacilli. LXIII. The Fatty Acids in the Phosphatide Prepared from Cell Residues from Tuberculin. J. Biol. Chem., 138:135.

With R. L. Peck. The Chemistry of the Lipids of Tubercle Bacilli. LXIV. Concerning Phleimycolic Acid. J. Biol. Chem., 140:89.

1943

The Chemistry of the Lipids of the Tubercle Bacillus. Yale J. Biol. Med., 15:311.

With R. E. Reeves, M. M. Creighton, and W. C. Lothrop.[1] The Chemistry of the Lipides of Tubercle Bacilli. LXV. Investigations of Tuberculous Lung Tissue. Am. Rev. Tuberculosis, 48:65.

1944

With S. F. Velick. The Chemistry of *Phytomonas tumefaciens*. II. The Composition of the Acetone-soluble Fat. J. Biol. Chem., 152:523.

With M. M. Creighton and L. H. Chang. The Chemistry of the Lipids of Tubercle Bacilli. LXVII. The Lipids of the Human Tubercle Bacillus H-37 Cultivated on a Dextrose-containing Medium. J. Biol. Chem., 154: 569.

With M. M. Creighton. The Chemistry of the Lipids of Tubercle Bacilli. LXVIII. The Lipids of Cell Residues from the Preparation of Tuberculin. J. Biol. Chem., 154:581.

With C. O. Edens and M. M. Creighton. The Chemistry of the Lipids of Tubercle Bacilli. LXIX. The Composition of the Acetone-soluble Fat of Cell Residues from the Preparation of Tuberclin. J. Biol. Chem., 154: 587.

With L. G. Ginger.[2] The Chemistry of the Lipids of Tubercle Bacilli. LXX. Concerning the Dextrorotatory Fatty Acids of the Acetone-soluble Fat of Cell Residues from the Preparation of Tuberculin. J. Biol. Chem., 156:443.

1945

With L. G. Ginger. The Chemistry of the Lipids of Tubercle Bacilli. LXXII. Fatty Acids Occurring in the Wax Prepared from Tuberculin Residues. Concerning Mycocerosic Acid. J. Biol. Chem., 157:203.

With L. G. Ginger. The Chemistry of the Lipids of Tubercle Bacilli. LXXIII. Studies on Phthiocerol. J. Biol. Chem., 157:213.

1947

With G. I. de Sütö-Nagy. The Chemistry of the Lipides of Tubercle

[1] Paper LXVI of the series is by S. F. Velick alone and is entitled "Concerning the Structure of Tuberculostearic Acid." J. Biol. Chem., 154:497–502 (1944).

[2] Paper LXXI of the series is by L. G. Ginger alone and is entitled "The Determination of the Terminal Methyl Groups in Branched Chain Fatty Acids." J. Biol. Chem., 156:453 (1944).

Bacilli. LXXV. Further Studies on the Polysaccharides of the Phosphatides Obtained from Cell Residues in the Preparation of Tuberculin. J. Biol. Chem., 171:749.

With G. I. de Sütö-Nagy. The Chemistry of the Lipides of Tubercle Bacilli. LXXVI. Concerning Inositol Glycerol Diphosphoric Acid, a Component of the Phosphatide of Human Tubercle Bacilli. J. Biol. Chem., 171:761.

1948

With N. Fethke. Chemistry of the Lipids of Tubercle Bacilli. LXXIV. Study of Acid-fastness of Acid-fast Bacilli. Am. Rev. Tuberculosis, 57: 294.

1955

With E. R. Long, D. Rittenberg, M. L. Karnovsky, and H. H. Henderson. The Carbon Metabolism of the Tubercle Bacillus. Am. Rev. Tuberculosis, 71:609.