NATIONAL ACADEMY OF SCIENCES

ARTHUR BECKET LAMB

1880—1952

A Biographical Memoir by

FREDERICK G. KEYES

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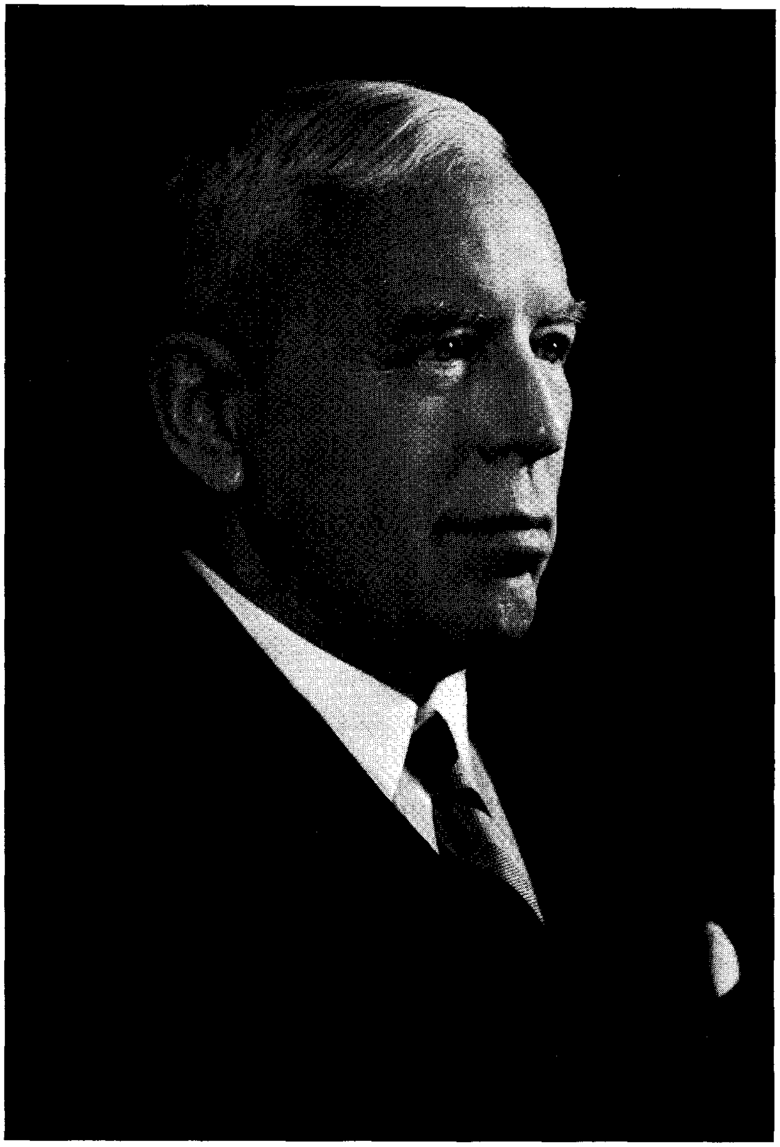

Arthur B. Lamb

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A MEMOIR deals with a restricted piece of history, a miniature. Unlike history, however, which deals with a multitude of figures, the evolution of a life of science, its initial orientation, its attainments and fulfillment crowd a tiny canvas. And yet, to paraphrase Edmund Burke,[1] an encounter, a particular circumstance or observation, a friendly remark, a teacher with the priceless gift of insight may change the face of science and almost science itself.

Arthur Becket Lamb's journey of life began at a time when the madness of Civil War and its aftermath of economic confusion were passing. The western world generally was in a period of peace. Unparalleled scientific productivity foreshadowed an unimaginably extended introduction of applied science in industry accompanied by an accelerated economic expansion.

Lamb was descended from a long line of New England forebears. On both paternal and maternal sides of the family, the New England founders were those having the courage and independence to break with an unpromising homeland and attempt survival in the New World. The first Lamb, Thomas, arrived in Massachusetts with his wife Elizabeth and two sons in 1630 from Nazing, some twenty miles north of London. Thomas was a founder of the First Church of Roxbury, the sixth in New England. His great-great-grandson

[1] "A common soldier, a child, a girl at the door of an inn, have changed the face of nature, and almost of Nature."

was a "Minute Man" and anticipated Paul Revere by marching from Charlestown to Roxbury on April 8, 1775. Like the great majority of immigrants, they were good farming folk.

Elizabeth Becket, Arthur Lamb's mother, descended from John Becket, who died in Salem in 1683; her immediate family were shipbuilders. Lamb's father, Louis Jacob Lamb, established himself in the jewelry manufacturing business in Attleboro, Massachusetts, where Arthur was born on February 25, 1880. A precious element in the early life of Arthur Lamb was the constant mutual understanding and affection between father and son. Someone has said that "directly after God in heaven comes father"—and Louis Jacob Lamb was unique in the role by virtue of his delicacy of perception, his gentleness, and his instinctive sense of inner unity. He was a deacon of the Murray Universalist Church of Attleboro and for years its Sunday School Superintendent. Respected by everyone, he died at the age of fifty-four, before Arthur reached the height of his career.

Among some of Lamb's notes describing scenes and events of his young boyhood is a record relating to his mother which runs: "She was more fiery in her temperament than father,—full of love and compassion for the good and the unfortunate, but unequivocal in her disapproval of what she thought was wrong or wicked. She had a warm, rich nature, but she was uncompromising and would willingly have gone to the stake for any of her cherished principles or beliefs. She also had great energy and ability. She was skillful with her hands, and in housekeeping a perfectionist. . . . Her quick mind, her fearlessness and her enthusiasm made her a leader, and incidentally, a persuasive speaker in public."

Mrs. Lamb evidently followed her son's progress with an intelligent interest, for he entered high school at twelve with the avowed purpose of thorough preparation for college. On Saturdays, instruction in drawing and lessons in German, a favorite interest of his mother, served to complete the week's activity.

The particular circumstance that touched the young student's life was the possession by the school superintendent of a fine six-inch Alvin Clark telescope. Through Mr. Tiffany young Lamb became tremendously interested in astronomy. In his junior year, the school was presented with an eight-inch Brashear reflector, and Mr. Tiffany put young Lamb in charge of it. With a copy of Webb's catalogue of double stars, a small group of students set out to observe every double star resolvable by the Brashear. Enthusiasm was somewhat dampened by the parents' objections to midnight sessions and three o'clock morning risings to view stars only visible at the awkward hours.

The town of Attleboro possessed a good public library, of which Louis J. Lamb was a trustee and which soon became a happy hunting ground for the active son. There were no required courses in science at high school aside from some physics, but Roscoe and Schorlemmer's treatise on chemistry in the school library captured the boy's interest, on the strength of which he obtained permission to carry out some experiments in the rudimentary school laboratory. Among other things, a series of surface tension measurements on water by drop-weight means were carried out and continued until reproducible results were obtained. The great adventure came, however, in a quite different direction.

Carpenter's comprehensive book on the microscope came into the circle of his library browsing, and soon a consuming interest in the wonders revealed by the microscope filled his waking hours. In a matter of weeks he knew the book by heart and was collecting catalogues from microscope makers round the world. Eventually he reached the decision to construct a microscope, and he spent a summer in the tool room of his father's factory, finally constructing an instrument resembling a Leland-Powell English model with improvements. The rack and pinion and optical parts, however, were purchased from the Bausch and Lomb Optical Company. The wondrous and beautiful life of streams and ponds of the surrounding countryside now became accessible to the lad and gave him ever-extending delight.

The happy years were slipping by, and father and mother were puzzled to know which college the boys[2] should attend. Roland and Arthur were in the same class, for Arthur had been advanced by skipping a grade. Among others, a friend and neighbor, Mr. Hayward, was consulted. The advantages of Harvard were glowingly expounded, but Mother Lamb had many detailed questions about student habits and practices. Yes, Mr. Hayward reluctantly admitted, there was some drinking on the part of students, and well—of course, certain other minor vices were not unknown. Did the New England mother hesitate? Not a moment. "Do you think I would allow *my* son to go to that den of vice? Never!" The authorities at the Massachusetts Institute of Technology were consulted, where, "Yes, he could be admitted," but not advisedly; the boy was too young. There was also Dr. Leonard, Dean of Tufts College Divinity School, and Mrs. Lamb's friend and pastor during her girlhood. He advised Tufts, and Tufts was the choice when Arthur was to enter college in the autumn of 1896.

The young man had a wide range of interest and considerable detailed, if unorganized, knowledge of physics, astronomy, chemistry, biology, and mathematics. The 1896 announcement of Roentgen's observations with X-rays stimulated his inclination toward physics. He had importuned his teacher of high-school physics to let him try to obtain a photographic impression of a key placed upon a photographic plate enclosed in a holder. Using the single-disk electrostatic machine and a Crooke's tube operated for hours continuously one night, an X-ray impression was secured and exhibited in the town.

Mathematics had always been one of the lad's greatest interests in high school. There were several text books on algebra in the school library, and by using all available spare time, the problems in each book were solved. Days were spent in devising a method for trisecting a triangle and constructing a regular pentagon. The principal offered to teach him trigonometry, which he did evenings.

[2] There were three brothers, Roland, Arthur, and Leonard.

Out of all the wide background of interest, the college subject Lamb selected for concentrated interest in September of 1896 was biology. All the required courses in the subject were completed and research was begun in the junior year. The paper, his first, appeared in the *American Journal of Anatomy,* volume 1 for 1902—"The Development of the Eye Muscles in Squalus Acanthias." The work was done for the greater part at the Marine Biological Station at Harpswell during summers and was presented finally as a thesis for the Master's degree.

Meanwhile, though biologists are not usually remarkable for any special interest in mathematics, Lamb took all courses offered by the Department of Mathematics, including differential equations, quarternions, and Newtonian Potential Function. To this array was added most of the courses in chemistry, besides four years of German, and courses in physics, Latin, French, English composition, English literature—and a course of ethics in the Divinity School!

Lamb was unusually popular with his college mates of both sexes, and not less so with the members of the faculty and their wives. For the full four years in college he was class president, sharing college fraternity life, and active as a member of the honorary societies. He was elected to Phi Beta Kappa in the junior year.

In the nineties the Tufts faculty was distinguished by the presence, among others, of a famous organic chemist, Arthur Michael, then in his early forties. Michael's influence on young Lamb grew steadily as one college year succeeded another, and after prolonged consideration zoology was abandoned for chemistry at the end of the senior year.

Research in inorganic chemistry was started in the fall of 1900 with an attempt to prepare iodine heptoxide. Michael had already obtained chlorine heptoxide. The heptoxide was not secured but meta-periodic acid was prepared for the first time and formed the subject for the first paper in chemistry (*Am. Chem.* J., 27:134, 1902). The attempt was also made to form selenium trioxide, but without success. However, the discovery of the reaction of acetyl chloride with selenic acid provided material for another paper.

A course of lectures by Bjorknes on hydrodynamics during the college year suggested an idea to Lamb which resulted in a biology paper entitled, "A New Explanation of the Mechanics of Mitosis." Another summer at the Marine Biological Laboratory at Harpswell enabled Lamb to repeat with the sand dollar the significant experiment of Jacques Loeb on the parthogenetic development of sea urchin eggs. The work was not published but interested Loeb greatly.

Professor Michael assigned to Lamb in the fall of the second graduate year a study of the isomers of the coumaric acids to prove whether or not it was possible to prepare an *allo* isomer similar to the known *allo* coumaric acid. Michael then blandly announced he was making a world tour, and would Lamb give his two advanced courses, inorganic and organic chemistry. In March the great man returned from Europe, spent a few hours at Tufts College, and set out for Japan. As the academic year closed, Lamb solved the research problem without benefit of the circumnavigator.

Lamb's interests had again begun to waver, and this time in favor of a subject somewhat new to the science practiced in American universities—physical chemistry. Professor Michael was disgusted, but Lamb was resolved. Maine was the summer home of Professor Morse of Johns Hopkins, whose technical developments for measuring osmotic pressure were attracting much attention. Calling at the Maine retreat, Lamb arranged to take up a problem with Morse in the autumn. A Tufts friend, also named Morse but unrelated to Morse of Hopkins, was to enter the Johns Hopkins Medical School, and the friends agreed to share rooms. At home in Attleboro the trunk was packed, and there only remained some farewell calls to complete, one to Professor Michael. Michael deplored the young man's perverse taste in science, remarking that very likely Hopkins was little worse than other places. An idea assailed him, and he asked, "Have you talked with Professor T. W. Richards?" "No."

"Well, you understand my low opinion of chemistry at Harvard, but since you have lived so long nearby, it would look strange that you had not met a man so distinguished in chemistry before going to Hopkins." Forthwith Michael wrote a note of introduction, and with reluctance Lamb sought out the tasteful home at 15 Follen Street, Cambridge.

Professor Richards was seated on the veranda. This most delightful and engaging of men talked of many things—of chemistry, physical chemistry in particular, and of its relation to the future of chemical science. Lamb departed filled with fresh zeal and reconsidered his plans during his return trip to the Attleboro home. The parents, after discussion with the son, left the decision to the young student without disclosing their satisfaction that he would not be in far-off Baltimore. A telegram to Morse and a second visit to Richards settled matters. Thus Lamb entered Harvard, and this important, if hurried, decision was never regretted.

Lamb made no attempt to receive credit at Harvard for the extensive advanced courses taken at Tufts. He took a course at Harvard in advanced organic chemistry. According to his notes, while admiring the clarity, orderliness of mind, and extraordinary memory for detail of his instructor, he soon perceived that organic chemistry as taught there had none of Michael's insight and incisive knowledge. "His course was dry as dust," is Lamb's succinct statement taken from his notes.

Research with Richards began with a problem Lamb brought with him—a study of the specific heat of solutions. The following summer he collaborated with Gregory Baxter on a small piece of research. The year had been stimulating and the experience satisfyingly valuable.

The second year was marred in the spring by an attack of appendicitis and Lamb was sent at once to Stillman Infirmary, where he was kept for a week. Protestingly he explained that unless he could finish certain experimental work, his thesis could not meet the May 1 deadline. On a promise to refrain from exercise and to return to the infirmary on the slightest recurrence of the attack, he was released. With the aid of a fellow student and a competent typist, Lamb worked nights preparing drafts for the next day's transcription; the thesis was finished, bound, and in Professor Richards' possession at eight-thirty in the evening of May 1. The following day the appendix was removed at Stillman Infirmary.

The Tufts requirements for the Ph.D. degree, except for final oral examination, had been completed before going to Harvard. The requirement was passed in early June of 1904, and the degree was awarded at the regular Tufts Commencement. Now the question was posed by someone of the faculty at Harvard, very likely a dean, as to the propriety of Harvard granting a Ph.D. degree to one who already had been awarded one at Tufts. The objection was not sustained, however, when it was brought out in the Faculty meeting that none of the candidate's work at Tufts subsequent to the Bachelor's degree had been counted toward the Harvard degree. The degree was awarded at the June 1904 Commencement, and the young knight of science returned to the lists of research armed with two redoubtable additions of armor. The year closed also with the award of a Parker Traveling Fellowship. The crowning scientific experience of that day was to be achieved—study in Germany.

A colleague some five years older, Gilbert N. Lewis, was instructor at Harvard during the years 1899–1900 and 1901–1906, having been awarded the Ph. D. degree in 1899. Lewis had been at Leipzig and Göttingen in 1900–1901, and the two men became congenial friends. Lewis' mind reacted quickly and effectively to all things, although he lacked the exceptional personal disinterestedness which was such an unusual characteristic of Lamb. Both men were aware, however, of the decisive role physical chemistry must play in revitalizing every branch of chemistry. Lewis had become aware during his year in Germany of the appreciation of the European physical chemists for the work of Willard Gibbs on the application of thermodynamic principles to chemical equilibria. Of the two, Lamb was by far the better prepared, by virtue of his mathematical training, to read Gibbs with assurance. Neither attempted, however, to use the great store of material as a systematic basis for any detailed treatments of particular applications which alone could spread among the young generation of American physical scientists a comprehension of the generality and latent fruitfulness of Gibbs' treatment. Both recognized fully the limitations of the treatment of gaseous equilibria on the basis of the ideal-gas laws and the simplified analogies applied to solutions.

Arthur Lamb left New York City for Europe on the "Carpathia" on July 12, 1904, visiting London, Amsterdam, Düsseldorf, Heidelberg, Basel, Lucerne, Interlaken, Zermatt, Zurich, and other places of interest in the course of the year's stay.

Incidentally, this was not Lamb's first European experience. It was the common practice of students to take an ocean voyage by cattle boat. Lamb's trip had been made in the "Anglian" with 500 head of cattle, 100 horses, and other livestock, out of New York on June 28, 1901. His chambermaid duties for the animals kept him well occupied but on July 8 Bishop's Light was sighted, and he landed on the 10th at Albert Docks in London. The tour of England and the Continent by bicycle could then be made for a modest sum. Lamb's total expenditure, according to his notes, which indicate no penny pinching, came to $550. Fifty days in Europe at an average of eleven dollars a day including every expense!

During the winter of 1904-1905 in Göttingen, Leipzig, and Heidelberg, Lamb's interest in the application of thermodynamics to gaseous chemical reactions was stimulated by the lectures on technical gas reactions given by Haber at Karlsruhe. The lectures appeared in book form during Lamb's European residence, and he formed the idea of translating the book in the interest of acquainting English-speaking chemists with this important application of thermodynamics. Professor Haber revised and rewrote many parts of the original 1905 edition for the translator. The translation of the first four lectures was in final form in the spring of 1906, and the completed book of seven lectures, *Thermodynamics of Technical*

Gas Reactions, finally appeared with the date 1908, published by Longmans, Green & Company.

Ostwald's laboratory at Leipzig during the first decade of the century was a center of intense activity in physical chemistry, and filled to overflowing with students. Lamb's work was actually under Professor Luther's direction, but the influence of Ostwald was all-pervading.

The fall of 1905 found Lamb back at Harvard as instructor in electrochemistry. However, in the spring a call was received, and accepted, from New York University to serve as successor to Professor Morris Loeb as Director of the Laboratory and Chairman of the Department. Upon taking up the new duties in the fall of 1906, somewhat of an unexpected impasse presented itself. Two of the senior members of the department regarded Lamb as having been "brought in over their heads," and the department staff believed an injustice had been done. In the end Lamb's innate generosity and fairness won the cooperation of everyone, and eventually the two most aggrieved professors became his loyal friends.

At New York University Lamb taught a variety of subjects, started his research, and joined the Chemist's Club. The club membership resulted in a wide acquaintance with chemists of every hue. He was elected secretary of the Bronx Society of Arts and Sciences, went to Europe every other summer, formed lasting friendships with many faculty members, was regularly promoted and made chairman of numerous committees.

Freedom from distractions for research and time for meditation were uppermost in Lamb's mind, and the years were slipping by, each with its additional increment of administrative routine and profitless detail. The years in New York City, however, were not entirely unproductive of research, and the publication of earlier results accomplished at Tufts and Harvard as well as the completion of the translation of Haber's book represented satisfying accomplishments. Two papers reporting new work did appear, but six very vital years had vanished.

In the fall of 1912, Lamb returned to Cambridge to become Director of the Chemical Laboratory of Harvard University. He was to stay there throughout the remainder of his years. It was the environment he loved, and indeed for him ideal because of early associations and the contacts with friends of his young manhood. Above all, here were favorable circumstances for conducting research. During 1912 an important piece of investigation was carried out. It concerned the measurement of densities by a novel method yielding results of extraordinary precision.

The return to Harvard in 1912 was the opportunity to construct a program of research in collaboration with graduate students, perhaps the only wholly satisfying form of teaching for the born scientific investigator. It was the opportunity Lamb had sought since high school, but the administrations of very few institutions of that day understood the significance, culturally or economically, of consciously developing a favorable environment for original investigation.

In collaboration with his graduate student, R. E. Lee, the densities of various carefully distilled water samples were found to differ by as much as eight parts in ten million. The measurements were part of a program of investigation of salt solution densities. These differences represent, so far as known, the first direct experimental evidence of the existence of a hydrogen isotope—although, of course, it was unsuspected at the time. If a sample of water containing one molecule of deuterium to 6,500 of hydrogen were removed, the decrease in density would amount to 170 parts per ten million. What a pity the variations of water density did not divert Lamb from his interest in solution densities.

The incidence of war in 1914 was a veritable world shock, morally and materially. The supplies of apparatus employed in United States universities in practically every branch of science originated abroad, largely in Germany; they were of particular importance for chemistry, which is so emphatically a laboratory science. The source of organic and inorganic chemicals, of glassware, and special apparatus suddenly ceased, producing an immediate hiatus in research and hardships in chemistry laboratory instruction.

The United States officially entered the war in April 1917, and in the early summer Lamb, at Professor Richards' request, undertook for Military Intelligence in Washington an examination of documents and papers supposed to contain invisible writing. The work was begun in the Gibbs Laboratory using a confidential manual transmitted by or originating with the French Secret Service. A conference with a United States Army representative at the War College in Washington resulted in the receipt of documents and letters which proved to contain little secret writing upon examination at the Gibbs Laboratory. Dr. Norris Hall and Dr. Emmett Carver joined Lamb in the work of devising new methods of producing secret writing, together with the study of methods for the development of secret communications.

The German army employed poison gas early in 1917, and presently plans for chemical warfare defense and offense began to preoccupy designated U. S. Army officers. In the late summer of 1917, Lamb secured leave of absence from Harvard and became a member of a research group to study gas warfare established by Dr. Manning, Chief of the U. S. Bureau of Mines at the American University in Washington, Dr. George Burrill, Director.

Lamb was put in charge of a section having responsibility for dealing with carbon monoxide hazards, with charcoal as an adsorbent, and soda-lime as a carbon dioxide absorbent. Presently the U. S. Army militarized the organization and made it the Research Division of the U. S. Army Chemical Warfare Service. Lamb suddenly found himself a lieutenant colonel and Chief of the Defense Chemical Research Section.

The expansion of Chemical Warfare Service was rapid and was accompanied by the formation of branch groups at universities and industrial laboratories. A considerable portion of Lamb's time soon came to be taken up in traveling about for conferences and in the details of organization of a rapidly expanding effort. Fortunately, as the fury of effort and strain mounted to a climax, it came to an abrupt halt on November 11, 1918.

Lamb's contributions during the war touched on both scientific and human problems. Out of his rich and broad experience in science, while he was barred by circumstances from active personal laboratory participation, he was able to suggest ideas and solutions to important problems which proved valuable. The provisions for carbon monoxide hazards arising from gun fire grew out of his continuing suggestions and knowledge and led to a satisfactory catalyst for the conversion of carbon monoxide in air to harmless dioxide. Another catalyst, Hopcalite, developed by Fraser at Johns Hopkins and by Merrill and Scalioni at the University of California, was also promoted by Lamb's interest. The Navy was provided with 20,000 canisters containing the monoxide protective device. Numerous other examples attest the stimulating effects of Lamb's vivid imagination sustained by an extraordinarily intimate knowledge of many scientific fields.

Following the armistice, everyone who cared about scientific pursuits was anxious to resume abandoned projects. The Research Division of the Chemical Warfare Service was established at Edgewood Arsenal, and Lamb was offered the post of liaison officer between the Research Division of the C. W. S. and the universities, a post he declined because of the loss of opportunity for scientific research and involvement in administration. About the same time Lamb also received an enticing offer of the directorship of the Research Laboratory through Mr. Lamme, Chief Engineer of the Westinghouse Machine and Electric Company, which was also declined for essentially similar reasons.

Lamb's inborn love of science went deep enough to let him know that a material success could be purchased only through loss of the satisfactions arising out of personally conducted research on problems originating from his own scientific interests. With the exception of the interlude from 1912 to 1917, he had been too largely diverted from the scientific pursuits he loved.

Shortly after the foregoing decisions had been made, Professor Arthur A. Noyes came to Lamb with a much more attractive proposal. Noyes at the time was a member of a special committee appointed by the President of the United States to study and report on how the immense power stations and nitrogen fixation plants built with tax funds as a war measure at Muscle Shoals, Alabama, could best be made useful, particularly for fertilizer manufacture. The committee, among other decisions, voted to send a mission to study nitrogen fixation in Europe, particularly in the occupied region of Germany. A second decision was to establish a laboratory for the study of nitrogen fixation. The President made his war emergency tax funds available for this purpose, and the Chemical Warfare Service Laboratory and equipment at the American University was assigned to the new laboratory.

Professor Noyes, for the committee, offered the directorship of the new laboratory to Lamb, who accepted at once on condition that two competent men would be appointed as associate directors, namely Dr. Richard Tolman and Dr. William C. Bray. After some discussion over salaries the arrangements were made.

The new laboratory was organized early in 1919. Meanwhile the European "Mission" was named, which included Lamb. It left in June and returned in September with valuable information which promoted the ultimately successful manufacture of cyanamide and derivatives for fertilizers.

In the course of the activities following the armistice, Lamb involuntarily became involved in patent matters. The C.W.S. had adopted a policy whereby members of the technical staff could file patents for inventions made in the course of their investigations. A patent department had been established for the preparation and solicitation of these patents. The government retained rights under all patents issued for government uses, but the inventors retained their rights for nongovernment use, both in the United States and abroad.

Under this policy a number of patents had been applied for and issued to men in various sections under Lamb's supervision. Lamb himself, alone and with others, had been granted several patents, some of which appeared to have commercial value. However, the prosecution and exploitation of the patents presented some difficulties. For example, the basic invention of the carbon monoxide catalyst appeared to have been made independently and simultaneously by two men in the University of California group and by another in the Johns Hopkins University. Further, the development of the catalyst and methods of manufacture had been carried out by still other investigators in collaboration. Finally, inventions for the use and construction of masks and canisters to use the catalyst were made by still other men in the section. The settlement Lamb effected in a situation ready for infection from envy, cupidity, jealousy, and self-esteem marks him as a man of unfailing patience, courtesy, and sagacity. The arrangement finally devised consisted of the following items suggested by Lamb and consummated through his force of character and an inherent lovable goodness.

The first item Lamb secured was an agreement among the coauthors of the basic invention by having them file joint patent applications. Their divergent university affiliations were recognized by coining the word "Hopcalite," already referred to, as recognizing Johns Hopkins University and the University of California, the alma maters in this instance of the coinventors. The name is now in use internationally. The second item was to pool the patents for "Hopcalite" with other patents for its manufacture and for the design and construction of masks and canisters in which it was to be used. Thus the group of patents furnished adequate protection for any purchaser contemplating manufacture and use of "Hopcalite" in civilian application. The third item was to select the six or more investigators in the section, apart from the patentees, who had contributed to the development of the invention and to allot to each an equitable fraction of the income, if any, from the group of patents. Lamb established an equitable and amicable arrangement. The final and not unimportant item was to negotiate a suitable offer from a reliable manufacturer, which was also soon accomplished, and an exclusive license was granted to the Mine Safety Appliance Company. Royalties in the amount of $250,000 were paid during the life of the patents and distribution to the members of the group was made by Dr. Fraser in accordance with the original allotments.

At the time the Fixed Nitrogen Laboratory was established in 1919, Richard Tolman and Lamb devised the setting up of a similar patent trust to that described in the case of "Hopcalite" patents, though more far-reaching as a cooperative arrangement. The plan comprised a formal, voluntary trust among the technical staff of the laboratory whereby each agreed to turn over to the trust any patent or patents granted, in return for which the patentee could acquire stock certificates of the trust in proportion to salary. Profit from the sale or licensing of patents held by the trust were to be distributed *pro rata* as dividends on each share of stock issued. However, a percentage, ten percent, of any income received from a patent was paid directly to the patentee. This trust prospered, and Lamb acted as trustee for many years.

The advantage of the foregoing described arrangement, aside from the financial, and relative to the customary automatic assignment of all the inventor's patent rights to the government, was the conservation of the interest of the investigators. Obviously the unrestricted private exploitation of patent rights by the individual inventors would lead to abuses, secrecy, jealousy, and lack of cooperation. The system as devised by Lamb and Tolman promoted the free interchange of ideas and cooperation, and excellent *esprit de corps* developed.

The organization of the extensive laboratories and large staff of the Fixed Nitrogen Research Laboratory required two years of sustained effort. This chief objective of the assignment having been completed, Lamb returned to Harvard University after three years of leave of absence.

Lamb returned to Harvard in 1921 to his position as Director of the Chemical Laboratories and Professor of Chemistry. An event which was to absorb a considerable fraction of his time, thought and energy for more than thirty years had, however, already occurred.

The *Journal of the American Chemical Society* (founded in 1876) had in 1917 grown to occupy an increasingly important position in the growing contribution of the United States to chemical science. Now, with the conclusion of the war, the prospect of a greatly accelerated progress of all scientific research, and especially chemistry because of its practical applications, was in clear prospect.

Professor William A. Noyes, the able editor of the *Journal* since 1902, was approaching sixty years of age. He foresaw the greatly expanded role of the *Journal,* and Lamb's qualities did not go unobserved by this intelligent and wise friend of the Society. Professor Theodore W. Richards approached Lamb about assuming editorial duties in 1917. Lamb viewed with dismay the toll editorship would entail on his time for scientific investigation and the exercise of his influence through cooperative scientific research with graduate students. Lamb was vividly conscious, as were indeed others, of the tremendous, even explosive expansion which was about to take place in graduate study in the sciences, and particularly chemistry. The influence of the *Journal* was in such an event of decisive importance. In the end he accepted the editorship, the while fully aware of having yielded up all hope of attaining the dream of his graduate years. There was a large streak of Lamb's mother in his composition. His mother's urge to bring her mind and action to bear in the direction of what appeared to be the greatest social good lived on strongly in him.

Lamb became a great *Journal* editor and toiled at an increasingly voluminous deluge of manuscripts nearly to the end of his days. From continuous association with him over forty years, the writer knows how few evenings in the year saw retirement before prolonged attention to editorial obligations. Fortunately he was never without the loyal aid and counsel of his associate editors. His system of manuscript review was efficient, and is still the most satisfactory known, although at times causing impatience to arrogantly confident authors.

Lamb's patient and balanced sense of fairness seldom failed, however, to win the respect and confidence of the very large number of contributors to the most widely circulated scientific journal in the world: five million copies in 1951.

Lamb's return to Harvard in 1921 was a welcome change. He at once applied himself to another problem which had for years been under active discussion by the chemistry group. Boylston Hall, the home of the chemistry staff long before 1900, was now inadequate to an intolerable degree. General college enrollment was increasing rapidly, but the need for staff, space, and facilities for graduate study had begun to grow incredibly under the combined stimulus of the National Research Council Fellowship project, supported by the Rockefeller Foundation, and of the mounting demand for mature scientifically trained persons for university as well as industrial posts.

The design and construction of the new laboratories on Oxford Street in Cambridge, the extensive Mallinckrodt and Converse Laboratories, was begun. The need for foresight and imagination to provide laboratory space and the complex facilities for science in a period of unprecedented expansion was a demanding task. The elaborate system of heating, and forced ventilation to remove fumes, together with refrigeration plant, machine shop, and glassblowing facilities as well as storage and distribution problems were worked out as a collaborative enterprise on the part of the entire staff. The result has proven highly satisfactory.

Not only did Lamb carry through the building design with architects and supervise the design and installation of the physical equipment, but he occupied himself with the raising of funds for the new laboratory. He was also charged with the design and construction of the Radcliffe College laboratories.

On December 27, 1923, Lamb married Miss Blanche Anne Driscoll of New York City, and presently they settled in an attractive home on high ground in a quiet section of Brookline. The exceptionally commodious and spacious dwelling responded rapidly to Mrs. Lamb's well-developed artistic sense, to Arthur Lamb's unbounded joy. His shifting mode of life since leaving his parents' home had irked him greatly, for his sense of order and beauty was a marked characteristic.

In spite of the growing editorial duties, the details connected with the progress of the new laboratories and some undergraduate teaching, Lamb found time for research. Indeed, this effort was a relaxation from the routine duties, thereby providing in his case an intellectual stimulus. For physical relaxation there were two out-of-doors resources, tennis and mountain climbing; the first a life-long habit, the latter an interest acquired during his student days in Europe. He gave himself vigorously to both diversions and became a member of the American Alpine Club. Besides these activities he enjoyed contract bridge, billiards, and in his younger days dancing. He was also widely read in history and biography, a taste acquired before entering high school.

The investigations undertaken during the war were, of course, carried out to the point of supplying instant practical chemical warfare needs but were usually incomplete as publishable scientific reports. Lamb had been occupied with completing these items of research, beginning immediately upon his return from the European "Mission" trip in September 1919. Six papers appeared by 1922, and laboratory work on problems suggested by the continued postwar work was reported upon from 1923 to 1925.

Lamb's original scientific interest was in biology; then, in succession, in inorganic, organic, and finally physical chemistry. Throughout his active career he maintained a lively interest in all these branches of science, but from the time he returned to Harvard in 1912, experimental effort was confined to problems in inorganic and physical chemistry. He taught inorganic chemistry, or "general chemistry," to undergraduates and never ceased to derive satisfaction from the experience. Indeed he published a "Laboratory Manual of General Chemistry" (Harvard University Press, 1914-1916) in the early years of his teaching. Doubtless, since he was one who could never be content to read a text to his classes, the topics presented suggested lacunae which he was prompted to fill out or complete by added research.

His liking for undergraduate teaching was similar to that of Professor Arthur A. Noyes, who believed the best purposes of the university were served when the most mature scientific faculty members gave their best effort to teaching the early-year science courses. Both men toiled unceasingly to perfect their undergraduate courses, and both were abundantly rewarded through the successful careers of numerous inspired students.

In 1923, an eventful year for Lamb in other respects, he was elected to membership in the National Academy of Sciences, and in this year also his Alma Mater, Tufts College, conferred upon him its honorary Doctor of Science degree.

Editorial duties had by 1923 settled into a steadily accelerating rate of increase which was to continue until the entry of the United States into the Second World War. In 1920 the *Journal of the American Chemical Society* comprised per year about 1,500 pages, and in 1940 this figure had advanced to 3,700; the membership of 254 in 1876 had risen to more than 25,000 in 1940. The *Journal* had become the most widely distributed journal in the world and was self-supporting without advertising income.

The editorial procedures introduced and perfected by Lamb have, of course, been a major factor in the rise of the *Journal* to its position, not only as the most widely circulated scientific publication but as the broadest in scope. Since its editor exercised an incisive influence on the world-wide diffusion of the results of chemistry research in the United States and internationally from 1917 to 1949, a brief sketch of the background of the development is a proper part of this résumé of Lamb's career.

The American Chemical Society was organized in 1876 and began publication of its proceedings on March 6, 1879. About this time the increasing number of students returning from graduate experience in German universities was producing a rapidly increasing stimulus on chemistry research at Johns Hopkins, Harvard, Yale, and other universities. Publication facilities were very restricted. Professor Dana, editor of the *American Journal of Science,* stated, for example, that his journal could not accept more than fifty pages of chemistry research material. At somewhat the same time, however, Ira Remsen of Hopkins established his own journal, named *American Chemical Journal.* He was able also to enlist the support of most of the chemistry contributors in the universities. "Remsen's journal" filled a growing need and was deservedly successful. However, this success was not helpful to the prosperity of the *Journal of the American Chemical Society,* while the appearance of the *Journal of Analytical and Applied Chemistry* brought no added comfort to the Society's journal. Competition was not, however, the central difficulty. The real difficulty was that the American Chemical Society was not yet a national society but a New York City organization.

In 1893 Dr. Hart, editor of the successful *Journal of Analytical and Applied Chemistry,* expressed an idea which promised to resolve the competitive impediments affecting the Society's journal. He offered to discontinue his own journal as such and to assume the editorial duties of the *Journal of the American Chemical Society.* He became editor and continued until 1902, when Professor William A. Noyes of the University of Illinois assumed the duties. Very shortly Noyes sought Society approval for incorporating in the *Journal* the *Review of American Chemical Research,* a publication established by Arthur A. Noyes in 1895 at the Massachusetts Institute of Technology. This plan prospered, and W. A. Noyes brought about the publication in 1907 of *Chemical Abstracts.* There followed in 1909 the journal *Industrial and Engineering Chemistry.* Finally, in 1923, the *News Edition* appeared, subsequently named *Chemical and Engineering News.* Another event of great importance to the Society was the merging of "Remsen's journal" with the *Journal of the American Chemical Society* in 1913.

The foregoing references indicate how the appearance of a multitude of special journals, which are an accompaniment of a progressive specialization, was avoided. The *Journal,* comprising material for sections entitled "General," "Physical," "Inorganic," "Organic and Biological," has continued and has long since entered the period where the boundaries between specialties have broken down. The value of the general journal seems established, and Lamb's steady adherence to the plan is now justified.

The editorial policy brought to perfection by Lamb has had a very profound influence in uniting the Society's members, but above all it has guided the younger members beginning publication to value an objective, discriminating approach in reporting their results. This took toll of the editor's time and patience, but it has been a contribution to civilization of more than immediate importance to the material progress of science. The editorial scheme encompasses the examination of all manuscripts by discerning experts in each special field. The examiners are selected out of the continuing experience of the editor and are expected to detect in a manuscript neglect of known facts, errors of procedure, experimentation, and deduction, as well as faults of presentation. The editor guides his examiners to seek out and recognize what is good and not to overstress the defects as grounds for rejection; the aim being to salvage any contribution however fragmentary. Lamb held it a greater humiliation to find that anything good or useful had eluded publication than to have an occasional faulty manuscript slip by.

A further provision Lamb exacted of his reviewers was a report stating clearly the grounds for criticism, accompanied by constructive suggestions regarding how deficiencies might be remedied or corrected. The examiner's function was to supply the author with competent suggestions and friendly assistance. The examiner's sympathetic report and helpful suggestions, transmitted to the author, were rightly believed by Lamb to be the most sustaining foundation of good editing.

It may be questioned, as a practical matter, whether such time-consuming examination of manuscripts could be made of a thousand and more papers coming to Lamb each year, especially when they covered the whole field of the science. Besides, there was never any money to pay for the examinations. To meet this problem, Lamb gradually developed what he called his "referee system." These referees might be members of the Associate Editorial Board, but more often they were specialists in the various fields found by trial, and some error, to be qualified by knowledge, insight, and personal attributes to act as referees according to the editor's standards. Disapproved manuscripts were sent to several referees and usually to a member of the Board.

Lamb had to sustain criticism, particularly during the twenties, of his editorial procedure, the most serious objection being the delay in publication. By experience, delay was largely eliminated as Lamb was able to get prompt action and competent referees. Very soon authors found that the interval between the receipt of a paper and publication was not noticeably longer, and sometimes even shorter than with other comparable journals. Where delay occurred, there was an advantage to the author and his readers, since he had been assisted to a more creditable publication.

Lamb's contribution to the diffusion of science is now everywhere acknowledged. Under his editorship the *Journal* became the largest and cheapest as well as the most widely distributed research publication in the world. No less outstanding as a contribution has been his civilizing influence on the young developing contributors, who through the Lamb editorial procedure were brought into contact with their older and more experienced colleagues.

In 1933 the American Chemical Society elected Lamb its president. The obligations of the office took him to every state in the republic, and he enjoyed the experience without qualms engendered by absence from the editorial desk. He knew his staff and faithful Board would carry on the editorial task without the slightest faltering.

On July 24, 1935, Lamb suffered the most devastating of calamities. Mrs. Lamb was preparing to accompany her husband to California when information came to the laboratory that she was grievously stricken. David, aged nine, and Deborah, seven, with their sorrowing father accompanied their beloved mother with heavy hearts on the last short journey. Lamb rallied from the blow slowly at first, but the immediate needs of the children drew upon his reserves of faith and courage. He arranged to be at home more consistently and rarely missed the dinner hour or Sundays for the ensuing fifteen years.

In 1929 Lamb received the Irving Professorship of Chemistry at Harvard, which he held until his retirement. The honors that came to him were many and significant; the William H. Nichols Medal of the New York City Section of the American Chemical Society on March 5, 1943, "for his investigations in inorganic and physical chemistry, leadership in defense against poison gas, and as a teacher, administrator, and editor." The medal was founded in 1902 by Doctor Nichols, a charter member of the American Chemical Society, "to stimulate original research in chemistry."

At the June 1944 Tufts College Commencement, the Hosea Ballou Medal for distinguished service was awarded to Lamb. In 1949 the highest award of the American Chemical Society was made to him at its 116th national meeting—the Priestley Medal; and in 1951 he received the Austin M. Patterson Award in Dayton, Ohio, on May 8. On this occasion Lamb paid tribute to Doctor Patterson, whose editorship of *Chemical Abstracts* from 1908 to 1914 had been fundamental to its establishment. The same year saw him elected Honorary Fellow of the Chemical Society of London.

Retirement from the editorship of the *Journal of the American Chemical Society* took place on December 31, 1949, bringing to a close his thirty-one years of uninterrupted service which had brought the *Journal* to a position of preeminence among scientific periodicals. A testimonial dinner tendered by his friends and admirers at the Mayflower Hotel in Washington brought him genuine satisfaction.

Arthur Lamb's religious convictions seemed to arise from a conscious sense of his inner unity with the world in which we live. He grew up in a liberal-thinking family of Universalists going back to his great-great-grandfather. In boyhood he was a charter member of the Sunday School, and later he joined the Murray Universalist Church of Attleboro. Following his marriage he transferred his membership to the First Unitarian Parish of Brookline, where he accepted the office of deacon, the duties of which he discharged faithfully until his death. He was for many years a member of the Board of Trustees of the Brookline Public Library.

Lamb kept his desk at the Oxford Street Laboratory, and laboratory work satisfied the queries arising from his reading and technical interests. His faculties, skill of manipulation, and quickness of perception seemed undiminished. He had, however, experienced a heart disability, and followed the advice of his physician friend with fidelity. He suffered a fatal attack in May 1952. On a beautiful day, the fifteenth, he was being driven home by his daughter after a day's work at the laboratory. Without warning, the soul of a gentle and kindly man suddenly made its flight.

The forty-six scientific papers of Arthur Lamb cover a wide range of chemical interest. His addresses on scientific topics and his book reviews make a formidable ensemble, which with his editorial correspondence was staggering in amount and variety for over thirty years. In addition to all this, however, there are sixteen patents issued over the years 1919 to 1932. His industrial consulting work and court services were also continuous and preoccupying over many years.

Under Michael's influence, following his work in biology as indicated earlier, Lamb began chemistry research in the inorganic field. However, he was not one who could be content to degenerate into an increasingly circumscribed specialist. He arrived at physical chemistry at a period when the impact of this branch of chemistry promised to illuminate extensively the established branches, organic and inorganic—and indeed biology, and especially physiology. Moreover, Gibbs' work on thermodynamics had made a profound impression for its importance and generality in interpreting chemical and physical change. Lamb was one of the few Americans who, assisted by his training in mathematics, sensed the value of Gibbs' contribution, as yet unknown in the United States in 1900. His work in Richards' laboratory on his own problem of reaction heats in liquids is an illustration of his decision to explore interpretations of his results along more general lines than had been previously attempted. His translation of Haber's *Thermodynamics of Technical Gas Reactions* is another illustration of his effort to aid in the introduction of exact thermodynamic theory as a means of interpreting and correlating experimental results.

During the New York University period, Lamb began his work on the cobalt amines and joined with M. A. Rosanoff and F. E. Breithut in their work on binary mixtures. The apparatus design insuring phase equilibrium was Lamb's.

His ingenious method of measuring densities to an extraordinary degree of exactness was of this same period, and as stated earlier in this record, showed unmistakably that the density of water was variable in relation to its origin and history. Lamb stated on several occasions that the cause undoubtedly lay in the presence of an isotope of either hydrogen or oxygen, possibly both. Events over which control was difficult robbed him of the time to verify his convictions.

The Chemical Warfare duties undertaken before and during 1917-1918 caused Lamb to focus his attention on a large variety of problems, many of which he completed and extended for several years following November 11, 1918. The phenomena of adsorption had been exploited in gas-mask design, and Lamb's interest in understanding the relationship between the nature of the solid surface or adsorbent and the kind or chemical structure of the gas adsorbed was greatly stimulated. With A. S. Coolidge he carried out an extensive experimental investigation of adsorptive heats and the equilibrium relationship between the amounts of the substances adsorbed as a function of pressure and temperature. The analysis of the results of the measurements led to interesting and important generalizations, which may be summarized, briefly though incompletely, as showing that the specific energy released in adsorption on charcoal increased (unless the surface was "poisoned") with diminution of the mass of gas adsorbed, the temperature being held invariable. However, the total mass adsorbed was less for a poisoned or previously contaminated surface. The magnitude of the adsorptive heat proved to be about the same on an adsorbent independent of whether the latter was activated or not. The heat of adsorption was greater than the normal heat of evaporation for substances, and the excess was called the "net" heat of adsorption, proving to be nearly equal to the heat of vaporization. Otherwise expressed, the heat of adsorption came out twice the liquid vaporization heat. In brief, the implication was that the heat of adsorption had its origin in the attractive field of the surface carbon atoms upon the molecules of the adsorbed gas, and that for a given volume of the substance reckoned from the liquid phase, the adsorbed heat was nearly independent of the kind of substance. The subject of adsorption continued to receive Lamb's attention over the years, and a number of adsorbents were investigated down to 1940, particularly those of crystalline structure.

The early work (1902) on iodine oxides and their related compounds had led during the war period to Lamb's suggestion of the use of iodine pentoxide for the conversion of carbon monoxide into carbon dioxide (1919 paper with A. T. Larson, and 1920 with W. C. Bray and J. C. W. Frazer). This important compound, iodine pentoxide, and related oxides have a practical importance not yet fully explored. Lamb continued to pursue the subject all his life; however, no reported work bearing his name appeared after 1924.

The subject of catalysis was from his graduate years a phenomenon of continuing interest. Lamb was impressed, however, with the apparent extreme complexity of the subject. He hesitated to publish, since he believed the literature was overcrowded with hastily conceived bits of research, thereby causing confusion. He finally did publish with W. E. Vail the results accumulated from a long-considered and carefully planned investigation of the catalytic oxidation of carbon monoxide. The rate of monoxide oxidation as influenced by small amounts of water vapor and of carbon dioxide, which under differing conditions exerted now an accelerating, now a retarding effect, was explored with care. The retarding effects of extreme dryness on certain gaseous and liquid reactions had been reported during Lamb's student years. He saw in the phenomena of adsorption a possible explanation of the puzzling gross catalytic effects observed. The results of the investigation confirmed Lamb's supposition regarding the role adsorption played in the catalytic oxidation of both hydrogen and carbon monoxide with much interesting and significant detail.

The subject of catalysis was involved in Lamb's attempt (with L. W. Elder, Jr.) to overcome by means of catalysts the sluggishness of the oxygen electrode. This relates to the problem of realizing a fuel cell by which the free energy of combination of hydrogen with oxygen is converted directly to electrical energy. A grave difficulty has always been encountered at the oxygen electrode, where polarization sets in on withdrawal of the smallest currents. The investigation resulted in promising electrodes involving accessory catalysts whereby higher current densities, higher potentials, and higher energy outputs were secured with much lower polarization.

It is unlikely that Lamb would ever have concerned himself with letters patent had not the responsibilities of his directorship of the Chemical Warfare Service Laboratory at Washington forced the subject upon his attention. A glance at the list indicates the larger number date from the period immediately following the active hostilities of World War I and the period of his directorship of the Fixed Nitrogen Research Laboratory.

The field of activity with patents marked Lamb also as an "expert" in patent litigation. He was called upon frequently, and he accepted proposals only when a painstaking appraisal of the issues involved convinced him of the rightness and justice of the cause. He was a wary and convincing witness in court, and his technical assistance to the lawyers in the preparation of briefs was particularly valuable because of his wide range of knowledge.

The years following Lamb's formal retirement from Harvard and his editorship were not accompanied by any perceptible diminution in mental powers; his memory, his enthusiasm, his quick grasp of detail, his rational optimism remained intact to the last day. His physical constitution had also lasted well under strains that very few men could endure for nearly forty years. The heart disability which became manifest in the last few years, a smaller inconvenience to most men, was onerous to one of his accustomed activity.

Lamb had in high degree the gift of friendship. In Cicero's words, he forgot nothing except injuries. There was no envy in his benign nature, a sure mark of having been born with great qualities of mind and heart. He was untainted by ambition, that "sin by which the angels fell," and empty of that inhibited sin, self-love.

He was a man, take him for all in all,
I shall not look upon his like again.

KEY TO ABBREVIATIONS

Am. Chem. J. = American Chemical Journal

Am. J. Anatomy = American Journal of Anatomy

J. Am. Chem. Soc. = Journal of the American Chemical Society

J. Exp. Zool. = Journal of Experimental Zoology

J. Ind. Eng. Chem. = Journal of Industrial and Engineering Chemistry

Proc. Am. Acad. Arts and Sci. = Proceedings, American Academy of Arts and Sciences

Proc. Soc. Exp. Biol. Med. = Proceedings, Society for Experimental Biology and Medicine

Trans. Am. Electrochemical Soc. = Transactions, American Electrochemical Society

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