OBITUARY NOTICES.

JAMES COLQUHOUN IRVINE.

1877—1952.*

DURING a period of fifty-seven years James Colquhoun Irvine served the University of St. Andrews in the successive capacities of student, lecturer, Professor, Dean of the Faculty of Science, and Principal. His services to Scotland's oldest seat of learning, particularly during his tenure of the highest office for more than thirty years, were such as to entitle him to take rank as little less than its second founder.

He was born at Glasgow on May 9th, 1877. He had one older brother and two younger sisters. His father, John Irvine, was a native of Maybole, Ayrshire; his mother, Mary Paton Colquhoun, came from Port Glasgow. John Irvine, a manufacturer of light iron castings, was descended from solid but undistinguished yeoman farmers who became associated with the rural weaving industry in Ayrshire until the introduction of steam-driven looms put an end to the cottage industries. In the words of his eminent son, " he was an accomplished linguist and musician, a capable mathematician, and a discriminative collector of books, mainly general literature. His outlook was that of the Lowland Scot—strongly Calvinistic—and he took pride in the fact that a Covenanting ancestor fell in the skirmish at Airdsmoss in 1680 and was buried in Glasgow Cathedral. Such scientific inheritance as I can trace comes from my father."

On his mother's side, Irvine's ancestors were entirely Highland, and her forebears followed the sea, either in the Mercantile Marine or the Royal Navy. Among them was a certain Alexander Colquhoun, master of a clipper in the China trade, and Captain James Colquhoun, R.N., who fell at Mandalay in 1882. This inheritance gave to Irvine, and also to his son, Nigel, an intense love of the sea and of sailing in small boats. Beyond this, as Irvine left on record, his mother " was a singularly beautiful character, and I owe to her anything I possess in the way of gentleness and sympathy for others."

Irvine considered that the most important early influence upon him was his father's insistence that the children should use the family library without restriction. His father was a close friend of Professor Henry Drummond (author of " Natural Law in the Spiritual World "), and the young Irvine, who often joined the two companions in botanical and geological excursions to Possil Marsh and the Campsie Hills, became the proud recipient not only of a simple microscope, but also of the telescope that Drummond had used in his expedition to Central Africa. To these early experiences Irvine ascribed in later life the start of his interest in science.

At the age of 13, this interest led him with an open scholarship to Allan Glen's School, Glasgow. Dr. John G. Kerr, headmaster of this pioneer school specializing in the experimental sciences, had been trained in the classical tradition, and he impressed upon his incipient scientists the value of linguistic studies: in fact, English, Latin, and French were compulsory for boys taking chemistry, physics, or engineering. Participation in games and athletics was strongly encouraged, and Irvine developed into a versatile runner. " The feet of the young Irvine were as fleet and nimble as his intelligence," wrote his contemporary, Dr. John Rogers. " He was a strong swimmer and he became no mean exponent both of golf and tennis."

When he left school in 1893, Irvine was firmly pledged to chemistry. For the next two years he studied at the Royal Technical College, Glasgow, under Professor G. G. Henderson, who urged him to pursue academic chemistry rather than to follow the usual course of training for a technical post; and it was on Henderson's advice that, in 1895, he migrated to the University of St. Andrews.

Here, originally in the capacity of lecture assistant, he became an ardent disciple of Thomas Purdie, F.R.S., Professor of Chemistry, who held an abiding place in his memory, and of whom he often spoke in the warmest terms. " The relationship between us," he used to say, " was almost that of father and son." It was Purdie who gave him the first vision of the true function of a university science department, in which teaching must be linked with an active prosecution of research. Purdie had worked in London with Edward Frankland, and in Würzburg with Johannes Wislicenus: a worthy pupil of this great German master, he became a pioneer of stereochemistry in Great Britain. In Irvine's opinion, Purdie's " election to the Chair in 1884 was the turning point in the history of Chemistry in St. Andrews, and it is not too much to claim that it was also a turning point in the history of the University."

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In 1891, on Purdie's initiative, a laboratory for practical chemistry, together with a modest research room, was presented to the University in memory of his uncle, Thomas Purdie, of Castlecliffe. More than this, by virtue of an unexpected inheritance, Purdie was able, in 1905, to follow up the original benefaction by handing over to the University a new building for chemical research, containing a lecture theatre. This institute, the first of its kind to be built in Scotland, was equipped and also endowed by the donor; and, equally important, Purdie gathered around him and inspired a band of enthusiastic young research workers.

It is not easy to convey any just conception of the condition of the University as Irvine saw it in his early days: here was an institution, it is true, deeply rooted in time; but marked by poverty, a paucity of students, and a sad lack of proper buildings and equipment for the teaching of science. He listened to Purdie's lectures in a primitive room furnished with a curved lecture-table. "The uncomfortable benches with high backs were richly carved with names and legends left behind by many generations of idle students; the wind, untempered by central heating, drifted continuously into the room, which was warmed only by an enormous open fire, replenished during each lecture hour by the Janitor, who was always greeted with grateful applause." This is Irvine's own description.

The small research room of 1891, with its high windows, looked northwards to the sea across a grassy slope leading down to the large College Lawn, or Professors' Bowling Green; and similar windows at the south end of the teaching laboratory offered an exquisite vista of another lawn, with a garden and trees. Here was an idyllic setting, reminiscent of Giessen and Liebig, some fifty years before. Moreover, the spirit of Giessen permeated the St. Andrews laboratory. In Irvine's early days at St. Andrews, teaching ended in mid-March; but Purdie and his group of keen workers stayed on through the late spring and summer, emulated only by William Carmichael McIntosh and his biologists in the Gatty Marine Laboratory. With all his capacity for arousing the enthusiasm and devotion of his pupils, Purdie was no narrow specialist. In Irvine's own words, his pupils "learned to appreciate that there is music beyond the range of students' songs, and literature other than the records of scientific papers. Round his study fire, the philosopher, the theologian, and the traveller were wont to gather." Such were some of the early influences brought to bear upon the future Principal of the University.

Irvine graduated B.Sc. with "special distinction" in chemistry and natural science in 1898; but even before graduating he had begun research work with Purdie on the optical resolution of lactic acid. After taking his degree he spent another year at St. Andrews, during which he continued to work with Purdie on the application of the "silver oxide reaction" to hydroxy-ethers, in an experimental verification of the Wiedemann–Landolt law. In 1899 he was appointed to an 1851 Exhibition Scholarship and went to Leipzig in order to work under Purdie's former teacher, Johannes Wislicenus, and also to study under Ostwald. In addition he attended lectures by Beckmann, Stobbe, and Pfeffer. He worked in the Erstes Chemisches Laboratorium, with the initial aim of synthesizing phenanthrene; and in 1901 he gained the Ph.D. degree, his thesis being entitled: "Ueber einige Derivate des Orthomethoxybenzaldehydes."

In a brief note on this period, Irvine wrote: "I found Wislicenus stimulating and lovable; Beckmann, jovial and interesting; Ostwald, aloof and completely indifferent to students specializing in organic chemistry. Purdie was the first English-speaking student to collaborate with Wislicenus, and, so far as I can trace, I was the last. From the point of view of scientific education I found Germany disappointing. This may in part be explained by the fact that my sojourn there coincided with the period of the Boer War and the lot of the *Engländer* was unenviable."

From Leipzig Irvine returned to St. Andrews, where the prospect of a junior position under Purdie proved more attractive to him than offers elsewhere of academic positions having a superior status, since this crucial decision enabled him to begin investigations on carbohydrates. This new line of work arose ultimately from the high standard of accuracy at which Purdie aimed in all his researches, and which extended to his measurements of optical rotatory power. It was through tracing to the source certain irregularities of optical rotation that Purdie and his collaborators encountered the celebrated "silver oxide reaction," which was to mean so much to organic chemistry, and to direct the trend of chemical research at St. Andrews for many years to come. This reaction, discovered by W. Pitkeathly, a young St. Andrews graduate, and developed by G. D. Lander, permits of a remarkably smooth and efficient alkylation of hydroxyl groups through treatment of the hydroxy-compound with dry silver oxide and an alkyl iodide. To paraphrase a saying of A. W. Hofmann: "Had the St. Andrews School done no more than discover the silver oxide reaction, its name would still deserve to be inscribed in golden letters in the records of chemistry."

It was some time after the discovery of this reaction that the possibility of applying it to fundamental problems of structure in the study of carbohydrates flashed across Irvine's mind while he was engaged on his *Doktorarbeit* under Wislicenus at Leipzig. Probably the sensitive sugars, being polyhydroxy-compounds, could be methylated by this gentle method. The resulting substitution of the hydroxyl groups, followed by hydrolysis and examination of the methylated fragments, might well supply the missing key to the molecular constitution of glucosides, disaccharides, and even polysaccharides. Purdie acknowledged his pupil's letter conveying this idea by a cautionary cablegram, indicative of its profound appeal to him, and to a large extent he financed the vigorous work in this new field, which started soon afterwards in the St. Andrews laboratory. Such was the origin of the famous carbohydrate research school of St. Andrews.

A short note left by Irvine on this matter of considerable historical importance in organic chemistry runs as follows : " My interest in the sugars was aroused through a special course of lectures given by Professor Hans Stobbe, who used in illustration Emil Fischer's original specimens. The idea occurred to me that the constitution of disaccharides and other compound carbohydrates might be solved by methylation, and these suggestions were communicated to Purdie in written memoranda. His advice was to complete my German degree and then return to St. Andrews (at his own personal cost) to test these ideas. Within a year I had isolated trimethyl- and tetramethyl-glucose—the first methylated sugars—and this was the beginning of a very fruitful line of work which has had a profound effect on our knowledge of carbohydrates. Many collaborators were attracted to take part in this work, among them Professor Sir W. N. Haworth, F.R.S., who for a number of years was a lecturer in my Department, and Professor E. L. Hirst, F.R.S., who was an undergraduate and later a research student in St. Andrews; also Dr. W. S. Denham, the first to methylate cellulose and to describe 2 : 3 : 6-trimethylglucose."

The fundamental importance of the new idea soon became manifest, and Purdie made available for the work every member of the laboratory that could be spared. It was in the midst of this work that he decided, in 1905, to build the new research institute to which reference has been made above. When he resigned, not long after the newly-organized department had got into working order, the prestige of the St. Andrews school of chemistry had risen so high as to attract a strong field of some two dozen candidates for the chair. The later history of the school vindicated the wisdom of the electors in their appointment to the vacancy of Purdie's most brilliant pupil, James Colquhoun Irvine, who had meanwhile graduated D.Sc. at St. Andrews in 1903.

And so, from 1909 to 1914, the fourth professor to hold this chair, with a band of enthusiastic collaborators changing gradually as time went on, delved ever more deeply into the intricate problems of the constitution of sugars. It was pioneer work, the blazing of a trail. The St. Andrews school of chemistry consolidated its international reputation. Emil Fischer, the *Altmeister* of sugar chemistry, sent from Berlin to offer an exchange of research programmes : " I wish to avoid any possibility of collision or competition," he wrote.

In 1915 Irvine was appointed Director of the Chemical Research Laboratories in succession to Purdie; but before this his widening interests had found expression in his election as Dean of the Faculty of Science in 1912, and as an assessor of the Senatus on the University Court in the following year.

The war of 1914—1918 interrupted the researches on carbohydrates and yet brought the experience of the St. Andrews school of chemistry into full play in the production of bacteriological sugars and related substances required for the military, naval, and other medical services of Britain and of certain allied countries. Some of these substances were very scarce, and new methods had to be devised for their preparation. Dulcitol, for example, had risen in price from 65s. per ounce in July 1914, to 300s. in January 1915, being then almost unobtainable. Supplies of Madagascar manna had ceased, and the total stock of galactose in Britain amounted only to a few ounces. It became necessary, therefore, to take the preparation back to lactose. Before long, the combined efforts of about two dozen workers at St. Andrews resulted in weekly quantities of 224 grams of pure dulcitol being supplied to the Government; the workers were occupied 7 days a week and from 10 to 12 hours a day in accomplishing this important task. Work on such indispensable substances as dulcitol, inulin, fructose, and mannitol was followed by the complete preparation, in quantity, in the St. Andrews laboratories of novocaine, an equally indispensable drug for use in place of cocaine. In addition, much work was carried out on the preparation of orthoform. In all, about sixty workers were engaged upon these tasks, the work being divided into nine departments, each of which was superintended by two research chemists.

The chemistry laboratories of the United College were transformed into what was practically

a research factory; since numerous operations on a large scale were required, it became necessary to install special apparatus and large-scale plant, and also to institute night-shifts. Many of the helpers were originally untrained novices, and the success of these arduous labours provided a high tribute to Irvine's powers and zeal. Often working with them far into the night, he stimulated his collaborators by an unfailing inspiration throughout a formidable undertaking upon which he brought to bear great organizing ability, sustained concentration, and a remarkable ingenuity of thought and technique. At the end of the war it was generally acknowledged among chemists that the St. Andrews Laboratory had made a contribution to the war-effort out of all proportion to its size and resources.

As a matter of historical interest it may here be interpolated that many years afterwards Irvine remarked upon the long and tedious series of investigations on the synthesis of novocaine that would have been saved at St. Andrews and other centres in Britain, if the easy preparation of ethylene chloro- or bromo-hydrin by passing ethylene into chorine water or bromine water had been known. In fact, the details of this concurrent work in the Organic Chemistry Department of Sydney University had been sent by the present writer to an authoritative source in England and its significance had been completely overlooked.

Some of the methods elaborated at St. Andrews in the course of the work mentioned above were successfully operated in factory practice. These war-time tasks, including other very difficult and objectionable work on mustard gas, hindered the expansion at St. Andrews of the fundamental researches in carbohydrate chemistry. Meanwhile, in 1918, Irvine had been elected a Fellow of the Royal Society. In 1919 he was able to return to his interrupted investigations in pure chemistry, albeit under heavy post-war handicaps; but in the following year his tenure of the Chair of Chemistry came to an end upon his receipt of the Royal Commission appointing him Principal of the University. Once more, a generation after Purdie's accession to the chair, in 1884, a turning point had been reached in the history of the University.

With the appointment of Professor Robert Robinson (1921) as head of the Chemistry Department, followed soon afterwards (1923) by another change, carbohydrate chemistry ceased to provide the central research theme in the Department. For some time Irvine strove to combine his new duties with personal work at the bench; but such a double task soon proved to be impracticable. Also he found himself unable to accept the Presidency of The Chemical Society, which he was invited to undertake. Nevertheless, valuable investigations in the carbohydrate field were continued at St. Andrews for several years under his general supervision, and also over a much longer period by G. J. Robertson and J. W. H. Oldham and their collaborators, as well as by A. Hynd in the Physiology Department. In particular, Irvine and his collaborators devoted five years during this period to refuting Pictet's claim to have synthesized sucrose, while at the same time they succeeded in synthesizing *iso*sucrose.

Ultimately, as Irvine became increasingly engrossed with administrative work and extramural interests, his effective participation in carbohydrate research ceased. This recession gave him profound regret. To the end, he remained a chemist at heart, and his interest in chemical research, especially in the field of carbohydrates, never waned. To the end also, every thesis submitted for a St. Andrews doctorate in chemistry passed through his hands and received his shrewd assessment. When the General Council of the University wished to recognize his fifty years' continuous connexion with the University, he decided upon the annual award of an Irvine Jubilee Medal to the most distinguished student in each of the Departments of Chemistry in the United College, St. Andrews, and University College, Dundee. He continued to take a lively interest in his former Department, although he never allowed that interest to operate in any way as a source of undue priority or advantage to it.

With Irvine's virtual retirement from active work in the laboratory, the main stream of carbohydrate research underwent a diversion from its source in St. Andrews. From St. Andrews, W. N. (later Sir Norman) Haworth, who had entered this field of research during his tenure of the senior lectureship in the Department, under Irvine, proceeded ultimately to Birmingham University, where he was able with numerous collaborators in an extended series of investigations to carry the studies of carbohydrate structure far on the way to their logical conclusion.

A distinguished pupil of Irvine (Professor E. L. Hirst) has said that " he was an inspiring teacher, and his lectures were models of clearness. More than that, they inspired in the students a love of chemistry and gave them a desire to take part in the discoveries that Irvine himself was initiating." " His lectures were fascinating," wrote another distinguished pupil (Dr. D. Traill), " and were presented in such a way as to give not only a knowledge of chemistry but a love of the subject. . . . He taught us more than chemistry, for to scholarship he added wit, to knowledge he added wisdom, and to sympathy he added discernment."

Most of the St. Andrews graduates in chemistry of Irvine's period passed from research into industrial chemistry; R. Fraser Thomson and D. Traill—to select two outstanding examples from many—have developed researches of the highest value in various industrial fields of chemistry. Among those who followed an academic career, C. B. Purves became Professor of Cellulose Chemistry at McGill University, Montreal; and E. L. Hirst, distinguished for his researches on carbohydrates, and in particular for his outstanding contribution to the molecular diagnosis and artificial synthesis of vitamin C, was elected F.R.S. in 1934, and has held in succession the chairs of organic chemistry at Bristol, Manchester, and Edinburgh. In 1948, Hirst was awarded the Davy Medal of the Royal Society, an honour that had previously fallen to four others connected with the St. Andrews school of chemistry, namely, Sir James Irvine, Sir Robert Robinson, Sir Norman Haworth, and Sir Robert Robertson.

Irvine had shown his administrative ability as Professor of Chemistry (1909—1920), as Dean of the Faculty of Science (1912—1920), and as assessor of the Senatus on the University Court (1913—1920); but few suspected the full extent of his latent powers until the broad opportunities afforded by his appointment as Principal (1920) and Vice-Chancellor (1921) unfolded themselves before him. During his thirty-two years of office in this exalted capacity, the University of St. Andrews changed out of all recognition, and he established a reputation as the most sagacious and energetic leader that the University had known in its long history of more than five centuries. His imprint will undoubtedly remain upon it for centuries to come. That he could have taken high office in other spheres, some of them far removed from Scotland, is well known; but, as he said, " I was in love with St. Andrews, and I was deeply grateful to St. Andrews, which had given me exactly the opportunity in life that I wanted. . . . No wonder that I started on my task with this deep feeling of gratitude and a fervent desire to do my very best."

Irvine found himself, a quarter of a century after he had entered its gates, at the head of an institution having a dual character, with centres in St. Andrews and Dundee. It was an institution to which, at this crucial point in a history marked by vicissitudes and crises, the emergence of a strong and determined leader was vital: in Irvine such a leader was found. The University, founded at St. Andrews by Bishop Henry Wardlaw in 1411, contained in that ancient city the United College of St. Salvator (1450) and St. Leonard (1512), together with the College of St. Mary (1537). University College, Dundee, founded in 1881, had been affiliated to the University of St. Andrews in 1897, and at the same time a conjoint Medical School was established in Dundee. All three of the St. Andrews Colleges had been originally residential; but at Irvine's accession residential accommodation in St. Andrews was limited to the large and flourishing University Hall for women and a small and somewhat precariously maintained residence (Chattan House) for men.

First and foremost Irvine revived the traditional residential character of the St. Andrews Colleges, and in so doing set a pattern of university development which has since been adopted so widely. That is one of many examples of his clear vision. " It is an arresting thought," he wrote in 1950, " that the Collegiate system which sprang into being so long ago should have survived essentially unchanged throughout the changing centuries and that the model carried forward from the Middle Ages by Oxford and Cambridge should have persisted in Scotland, and in our own time should have been considered worthy of adoption by the most famous Universities of the New World. Beyond question the Collegiate system has been of great advantage to St. Andrews, giving the university a characteristic quality denied to her younger sisters and binding her sons, now her daughters also, in a corporate life which strengthens their allegiance to the University of which Colleges are part." He emphasized in the Dow Lecture, delivered on September 21st, 1950, that " the full opportunities latent in the University could not be utilized to the full until Mr. Edward Harkness, who had a special interest in the welfare of the United College, made a series of gifts for purposes of his own selection designed according to a considered plan. This accelerated our progress beyond our dreams, and the result is the St. Andrews of to-day. The major part of the original Harkness donation was devoted by the donor to increasing the system of student residences."

The emphasis laid upon the residential system with its associated Harkness Entrance Scholarships, together with the institution of Regents (senior members of staff to whom their attached students may report for friendly advice and help), played a leading part in widening the field of recruitment of students and in raising their number to an economic level. Hand in hand with these developments, new chairs were founded judiciously, as opportunity offered, in every faculty of the University, and departmental staffs were augmented. In all directions the widening horizon of a resurgent University became evident.

Irvine cherished the picturesque attributes of his ancient University and drew into practical

service the pageantry and colour of the " College of the Scarlet Gown," that time-honoured College of St. Salvator which had been held in such reverence by innumerable *alumni*, from Napier of Merchiston and the Admirable Crichton, through Montrose and many another historical figure down the centuries to Andrew Lang and R. F. Murray, the student-poet. He encouraged the revival of the brilliant yearly pageant of " Kate Kennedy's Day," when the Lady Katharine (impersonated by a " beardless bejant ") issues from the portals of Crichton's hoary dwelling in the company of " her " uncle, Bishop James Kennedy, the founder of St. Salvator's College; and thereupon entering a garlanded coach, drives in procession through the streets of St. Andrews, the central figure in a richly-clad array of kings, saints, prelates, martyrs, knights, doctors, masters, and scholars, whose feet once trod the narrow wynds and cobbled ways of the ancient city.

In this and many other ways Irvine fostered the revival of old student customs and traditions. He took particular delight in the picturesque ceremonial of graduations and rectorial installations. His term of office as Principal was marked in its early stages by a wonderful sequence of Rectors in the persons of Barrie, Kipling, Nansen, Grenfell, and Smuts, whose selection for this office led in turn to some of his most valued friendships. His affection for the venerable foundation of Bishop Kennedy found an expression in the loving restoration and enrichment of the collegiate chapel, in 1931; while, in 1940, the ancient Katharine and Elizabeth bells in the chapel tower were recast. At the time of his death the restoration of the ruined chapel of St. Leonard's College was also well advanced, thanks to help from the Pilgrim Trust and the generous support of the Chancellor's Assessor, Sir David Russell; the reconsecration took place on St. Leonard's Day (November 6th), 1952. Another notable restoration during Irvine's period of office was that of the handsome historic Parliament Hall of the University Library, which was cleared of stacks in 1929 and converted into a Staff reading room. Apart from various structural improvements in the building, the Library was completely reorganized and modernized during the second quarter of the century, and concurrently the magnificent collection of nearly 400,000 books, pamphlets, etc., was for the first time adequately catalogued. In all these changes Irvine took a lively and helpful interest.

Towards the end of his career, during a clouded period of his life, Irvine experienced a happy interlude on the occasion of a visit of the Queen to St. Andrews on September 20th, 1950, for the celebration of the 500th anniversary of the foundation of St. Salvator's College. Academic pageantry, gay heraldic shields and flags, bright autumn sunshine, sparkling sea, invigorating air, historic buildings: all helped in the creation of a cavalcade of picturesque scenes, truly characteristic of Andrew Lang's " haunted town by the Northern Sea." Many years earlier, in 1929, Irvine had had the privilege of " capping " Her Majesty (then Duchess of York) as an honorary LL.D. of St. Andrews, during the ceremony attending her formal opening of the Younger Graduation Hall.

From what has been said it will be evident that Irvine's principalship was characterized by an extensive building programme. The foundation stones of the capacious Graduation Hall, presented to the University by Dr. and Mrs. James Younger, of Mount Melville, bear the names of Field Marshal Earl Haig (Chancellor), Sir James Irvine (Principal), and Dr. Fridtjof Nansen (Rector), with the date November 4th, 1926, when they were laid by those whose names they bear. Among student residences, St. Salvator's Hall dates from 1930, with an extension completed ten years later. This Hall, Hamilton Hall (formerly the Grand Hotel), and the enlarged St. Regulus Hall, each accommodates about a hundred men students, and McIntosh Hall for women students is of about the same size. Several smaller buildings were bought and adapted for use as men students' residences; other houses were acquired and converted into flats for members of the staff; and new houses for a like purpose were built in Irvine Crescent. A new building had been provided much earlier for the Departments of Botany and Geology; moreover, at the time of Irvine's death there was every intention of pressing forward vigorously with the building of the new Irvine Institute for Physics, a development urgently needed in order to relieve simultaneously the greatly overcrowded Departments of Physics and Chemistry in the United College, upon which there had been no building expenditure for more than a quarter of a century. One of Irvine's last building projects to be realized was the conversion of Deans Court, a romantic and historic house facing the ruined Cathedral, into an attractive residence for research students of all faculties, to remain open practically throughout the year, including vacations. A handsome stone building for accommodating the administrative staff was also nearing completion at the end of his régime. Besides all this, the welfare of students was enhanced by additions to the Unions and extensions to the playing fields.

Among many notable advances in the part of the University situated in Dundee were the

growth of the Schools of Medicine and Engineering and the expansion of the Chemistry Department of University College. In the period between the end of the second World War and Irvine's death, some £250,000 was spent on science buildings in Dundee. These rapid developments in Dundee, combined with the geographical handicaps imposed upon a University with centres situated on both sides of the Tay, were bound to give rise to growing pains. For a time, Irvine strove hard to compose these difficulties by accepting additional onerous duties as Principal of University College, Dundee (1930—1939). Eventually, however, it was found necessary to refer to a Royal Commission the whole problem of the organization of University education in Dundee, and its relationship with St. Andrews University. The Commission, which was set up in May, 1951, under the chairmanship of Lord Tedder, issued its Report in April, 1952, only two months before Irvine's death. That many of its drastic recommendations came as a severe shock to one who had nurtured the growth of the University for more than thirty years, cannot be doubted; Irvine questioned with profound misgiving the wisdom of trying to put so much new wine into a very old bottle. Yet, in his own words (1950): "Let it be an encouragement and an inspiration to each one of us to reflect that, within the history of our own times, obstacles so formidable have been met and surmounted . . . I have faith, unconquered and unconquerable, in the beloved University of St. Andrews."

Irvine's interests and activities, although focused on the University of St. Andrews, spread outwards as the years went by. He took a great and practical interest in preserving the historical character of the city of St. Andrews, to which he was devotedly attached, as "a gem of the North" (to use a term of Earl Baldwin) and a worthy shrine of his beloved University. He travelled extensively in Europe, India, the West Indies, the United States, and Canada. It is a striking tribute to his versatility that one so devoted to Scotland and so wedded to chemistry could render high service to the British Commonwealth in so many lands and offices. Usually his travel was determined by some particular mission. For example, he visited India (1936) as Chairman of the Viceroy's Committee on the Indian Institute of Science, and he flew to the West Indies (1944) as Chairman of the West Indies Committee of the Asquith Commission on Higher Education in the Colonies. As a result of the latter mission he became a prime mover in founding the University College of the West Indies, where the scarlet student-gown of St. Andrews may be seen in a new environment. A handsome gift of hundreds of valuable books which he made to this College affords a characteristic example of his personal generosity in causes arousing his interest and sympathy. The College was founded in 1946, and Irvine made further visits to Jamaica in that year and in 1947, 1948, and 1950. On this last occasion he was present at the installation of Princess Alice of Athlone as Chancellor, and he laid the foundation stone of the first students' residence, now known as Irvine Hall. The Report of Irvine's West Indies Committee has been called "the Bible of the Colonial University world." When the Inter-University Council for Higher Education in the Colonies was established in 1946, Irvine was naturally chosen as its first chairman.

Nearer home he rendered invaluable services to the Carnegie Trust, the Scottish Universities Entrance Board, the Scottish Education Department, the Forest Products Research Board, the Prime Minister's Committee on the Training of Biologists, the Pilgrim Trust, the Commonwealth Fund, and many other educational, cultural, and industrial organizations.

On the Carnegie Trust he acted as the representative of the University of St. Andrews for thirty-two years. As stated in the fifty-first annual report of the Trust (1953), "His association with the Trust was, in many ways, without parallel. He was the first but one of the Scholars elected by the Executive Committee when they began their Research Scheme, and never forgot the immense value of this aid received at a time when his powers were ripening. He became the personal friend of the founder and to him there was accorded the high distinction in 1935, at the great Carnegie Centenary celebrations in New York, of delivering the Memorial Address which, in grace of utterance and penetrative thought must always remain the best of all tributes to Andrew Carnegie's ideals and munificence. Possessed of a strong and retentive memory, allied to a sound judgment and knowledge of the essential features of the Trust Deed, Sir James became an indispensable member of the Executive Committee on all occasions when important decisions had to be made. Throughout its fifty-one years the Trust has experienced no loss more severe than this."

In the United States, to which he paid no fewer than ten visits, he was an ever-welcome guest. On various occasions he travelled widely in that country and delivered special lectures and eloquent addresses, as at Williamstown (1926), Princeton (1929), Yale (1931), New York (1932), and again at Princeton on the occasion of the bicentenary celebrations of that University in 1947. He was a fervent admirer of Benjamin Franklin and other great Americans. His

transatlantic reputation was so high that, had he so wished, he could almost certainly have become president of one of the great universities of the United States. His faculty of getting quickly upon terms with all sorts and conditions of men, and of entering easily into their interests, appealed greatly to the Americans. Among them he made many lasting friends, of whom perhaps the greatest was Edward Harkness. An intimate picture of the inception and growth of that friendship was given in *The Times* of June 30th, 1952, by Mr. Willard Connely :

" On December 11th, 1930, Sir James Irvine, after lunching with me as director of the American University Union in London, told me how he came to meet Edward Harkness. It was in 1925 that Harkness sent his old Yale friend, the late Max Farrand, to London to found the Commonwealth Fellowships. Farrand invited certain universities, and groups of universities, to nominate representatives to meet him in London and discuss the scheme. Oxford, Cambridge, and London of course all sent delegates, while Irvine represented Scotland. After Farrand, in a little talk, had informed the meeting that Harkness was providing 20 annual Fellows, the Oxford representative stood up and said : ' I think Oxford could fairly lay claim to six of these fellowships.' The man from Cambridge naturally arose (in his proper turn) and said the same thing. Nor was the delegate even from London University to be outdone; he doughtily put in for a third allotment of six fellowships. Irvine got to his feet. ' Gentlemen,' said he, ' I see that the number to be assigned to Scotland is minus four.'

" The next thing Irvine knew was that a note was handed to him by an attendant. It was from Farrand, and it read : ' Will you lunch with me after the meeting? ' Irvine nodded. Farrand, in consequence of this private talk, was inclined to make Irvine chairman of the British committee; but Irvine sagaciously suggested another arrangement. His view was that the chairman should be the chairman of the University Grants Committee, while Irvine himself would agree to be permanent vice-chairman, and four or five other members should be appointed for short terms from the universities in rotation. To all this Farrand acceded (as Farrand himself jovially repeated to me after he had become director of the Huntington Library), acceded so far that he in due course brought about a meeting between Irvine and Harkness himself.

" The impression that Irvine made upon the American philanthropist was so convincing that Harkness in the spontaneous and fearless American way suggested that they call each other ' Ed ' and ' Jim.' Irvine told me (at the same time after lunch) that one day in late summer, when he was a guest of Harkness at his country house overlooking Long Island Sound, and they were lying on the beach in their bathing-suits, Harkness suddenly said he wished to establish a further charitable fund in Britain out of gratitude for his own lineage. He asked Irvine to suggest trustees, and asked, ' Who is the most influential figure in English life to-day? ' Irvine promptly replied : ' Stanley Baldwin.' Harkness accepted him, and asked for other nominations. Irvine named Lord (then Mr.) Macmillan, and Lord Tweedsmuir (then Mr. John Buchan). Harkness agreed, and wanted one more; to make, with Irvine, of course, a committee of five. Irvine suggested Montagu Norman (to advise on investments of the fund, just as Buchan was to look after publicity). ' No,' said Harkness, ' I don't want any bankers.' Irvine then named Josiah Stamp; and the committee (consisting of three and one-half Scots, Baldwin's mother being Scottish) was complete. So it was that Harkness formed the Pilgrim Trust, and endowed it with $10m."

Irvine quickly established himself as an influential member of the Pilgrim Trust, that conception of enthralling originality and attraction (as the late Lord Macmillan termed it) which has meant so much, both materially and socially, to Britain. In particular, Irvine's acute and penetrating intellect, his sagacity, and his gift of concise and telling statement, enabled him to deliver judgments of great service in deliberations upon the multifarious appeals coming in to the Trust from so many quarters. One of the last projects that he commended to the Trust concerned the publication of a noteworthy book, *Recording Scotland*, which was issued (1952) as a result of aid obtained in this way.

He spared no efforts in deciding upon the merits of a particular case. I remember calling his attention in 1932 to the urgent needs of the ancient church of Westonzoyland, in Somerset, which had fallen into serious disrepair. He was much impressed by the magnitude of the fund that had been raised in the small local community, for he had a strong belief in self-help; but he seized at once upon the vital point that nothing could be done unless a specific case could be made out for this particular building. Upon hearing of its close connection with the Battle of Sedgemoor and its character as the virtual " cathedral " of that historic region, his serious attention was aroused. During a holiday in the West Country in the summer of that year he under-

took with me a long journey in order to make an anonymous visit to the church. He was satisfied, and told me that he would commend its claim to the Trust. Then, he added, quizzically: "Now, at last, I hope that the Westonzoyland cricketers will forgive you for bringing off those two hat-tricks against them in your youth!"

Irvine's services to the Commonwealth Fund were equally valued. In a letter to the present writer, dated August 28th, 1952, Mr. Malcolm P. Aldrich, President of the Commonwealth Fund, wrote: "Sir James Irvine was one of the original members, and later for many years Vice-Chairman, of the Committee of Award for the Commonwealth Fund British Fellowships; and for his zealous devotion in this activity the Fund owes him a great debt of gratitude. A close friend of Mr. Edward S. Harkness, first President of the Commonwealth Fund, Sir James shared with him a deep concern for the cementing of close relationships between Great Britain and the United States. He took infinite pains in the interviewing and selection of candidates for the Fellowships, followed with personal interest their progress in American Universities, and delighted in helping returned Fellows to find posts for which he knew they were best fitted. He left the imprint of his vibrant personality on our Fellowship programme. Sir James was associated also with other interests of Mr. Harkness in Great Britain, serving as a member of the Board of Trustees of the Pilgrim Trust and as an adviser on Mr. Harkness's gifts for the erection of St. Salvator's Residence Hall and the restoration of the Chapel of St. Salvator at St. Andrews."

Mr. Harkness' gifts to the University of St. Andrews, amounting altogether to more than £200,000, were devoted to these objects and to the Foundation of Harkness Entrance Scholarships for men students. The donor laid down specifically, in a letter to Irvine, dated October 20th, 1939, "that the Harkness benefactions are applicable only to purposes associated with the United College in St. Andrews." The University's greatest benefactor is appropriately commemorated by the Harkness windows in the Chapel of St. Salvator and St. Salvator's Hall. His portrait, depicting him in the doctoral robes of St. Andrews University, hangs in the United College Hall. This portrait, together with Oswald Birley's portrait of Irvine (1933), was presented to the University in 1933 at a ceremony presided over by the Chancellor, the Rt. Hon. Stanley Baldwin. Birley's portrait of Irvine hangs in the Senatus Room beside that of his teacher, predecessor, and friend, Thomas Purdie. There are later portraits of Irvine by Keith Henderson (1941) and A. E. Borthwick: the former is in the possession of the University and hangs in the dining-room of St. Salvator's Hall.

Irvine's long term of office as Principal saw the installation of four Chancellors and ten Rectors of the University of St. Andrews. At what proved to be his last graduation ceremony, conducted in the Parliament Hall of the University Library in January, 1952, he remarked that it was approximately the hundredth such ceremony at which he had presided. "We remember him," wrote Mr. D. N. Lowe, a former President of the Men Students' Union (1933—1934), "as Vice-Chancellor on formal occasions, at Graduations, Rectorials, and the like, a dignified and genial personality performing with grace and charm the time-honoured ritual of academic ceremonial. We recall the well-modulated voice delivering addresses marked by eloquence and wisdom and the warm humanity that marked all his relations with students." The circumstance that most occasions of this kind were graced by the attendance of honorary graduands and other eminent visitors contributed largely to Irvine's aquaintance with so many of the outstanding men and women of his day. Indeed, from the time of his taking office as Principal until the outbreak of the Second World War, St. Andrews witnessed a recurrent procession of great figures in the worlds of science, art, music, literature, drama, the Church, the Services, business, exploration, and many other fields of human endeavour and activity. Those were spacious days, which in retrospect appear as a Golden Age of high pageantry, rectorial banquets, and brilliant social gatherings at the Principal's House. In this picturesque and important part of his duties, and in innumerable other ways, Irvine was sustained by his gracious and dignified consort. During his student days in Leipzig he had become acquainted with a son and daughter of Mr. John Williams, of Dunmurry House, County Antrim. Robert Williams was studying the language and eventually became Professor of German in the University of Cambridge. His sister, Mabel Violet, was engaged in the study of piano and violin at the Leipzig Conservatorium of Music, under Hans Sitt, and Siloté, Court pianist at St. Petersburg. In 1905, James Colquhoun Irvine, by this time a lecturer under Purdie at St. Andrews, and Mabel Violet Williams were married. So began an influence of inestimable worth, that ran through his life and labours like a thread of gold. From that time onwards he was blessed with the unfailing devotion of one who created and maintained for him the background of a home life of surpassing happiness. Here he never sought in vain for help and inspiration; here he

found wise and sympathetic counsel amid doubts and difficulties; and here was ever comfort in the days of affliction that did not pass him by.

Of the three children of the marriage—one son and two daughters—the two elder (Veronica and Nigel Colquhoun) became graduates of St. Andrews University. After four years of arduous and distinguished service in the Royal Navy during the Second World War as a Lieutenant, R.N.V.R., their beloved son Nigel was accidentally drowned in 1944, while on short leave from his ship in Ceylon.

Irvine was awarded many honours. He was elected a Fellow of the Royal Society in 1918, and was knighted in 1925; in 1948 he became a Knight Commander of the Order of the British Empire. In chemistry he was Longstaff medallist of the Chemical Society, Davy medallist of the Royal Society (1925), Willard Gibbs medallist of the American Chemical Society, Elliott Cresson medallist of the Franklin Institute of Philadelphia, and Gunning Victoria Jubilee Prizeman of the Royal Society of Edinburgh. As a recognition of his services to Polish and Norwegian Forces in Scotland during the Second World War, he was invested with the Order of Polonia Restitua (Officer, Grand Cross), 1944, and the King Haakon Cross of Freedom (First Class), 1946. His numerous honorary degrees from the universities of the homeland, the British Commonwealth, and the United States, included the LL.D. of Glasgow, Aberdeen, Edinburgh, Wales, Toronto, Union College Schenectady, Columbia, and New York; the D.Sc. of Liverpool, Princeton, and McGill; the D.C.L. of Oxford and Durham; and the Sc.D. of Yale, Princeton, and Cambridge. He was a Freeman of the City of St. Andrews and an Honorary Member of the American Chemical Society, the American Philosophical Society, and the Franklin Institute of Philadelphia.

It is difficult to do justice in words to Irvine's many-sided character and personality. To quote the Rev. Dr. W. E. K. Rankin: "When we have said that there was the scientist and administrator and statesman, we have still omitted the dimension that truly separated and distinguished Irvine. It was something almost contradicting the rest of the man. He was practical, level-headed, far-sighted, and determined, and with it he was a Romantic and genuinely so." A richly-stored mind found expression in speech that could attain a rare eloquence and charm, whether at great moments or upon more intimate and informal occasions. A fellow-student, the Rev. Dr. George Blair, has testified that even in his 'teens he was possessed of "a vivid personality, with a grace of conversation that at once made him a centre of life and interest in any company into which he came." The same early friend has remarked upon his possession to a remarkable degree of "the priceless gift of mimicry," which never deserted him. He had also a pronounced rhyming facility, which he used effectively upon occasion in the impromptu production of amusing light verse.

Irvine was an admirable chairman, ever ready to lighten the routine of business with an apt anecdote or reminiscence, of which he preserved an inexhaustible store. Persuasive in argument, tenacious of opinions carefully formed, he showed the greatest determination and forcefulness in carrying through a project passionately held. "In the private sessions," wrote Sir Raymond Priestley, "when principles and practice were both threshed out, Irvine's urbanity was invaluable and his own firm opinions were a source of strength."

It was inevitable that a man of Irvine's force of character and clear-cut views should meet at times with criticism and opposition concerning policy. Differences of opinion and opposition are understandable; but they should not have degenerated into the nagging hostility that he had to face from some quarters over a long period, lasting without intermission until his death.

Irvine had a remarkable power of lucid exposition and of reducing a complicated problem to its essentials; at the same time he had an equally remarkable memory for details of all kinds. His recollection of the details of casual incidents was of the photographic type. Only two days before his death, during the luncheon interval of his last University Court Meeting, he spoke to me of a day spent many years before at Bicknoller, in the Quantock Hills, and specified minutely the circumstances of his meeting at a farmhouse with an unknown stripling then in his 'teens, but later destined to become a shining light in the world of cricket. Here also was an illustration of Irvine's abiding interest in radiant youth and in games, athletics, and sports of all kinds. He maintained his own proficiency in tennis, golf, and swimming until fairly late in life, and he was passionately fond of fishing. He read extensively and took a particular interest in accounts of polar exploration.

All through his life he had a discerning sympathy with youth. He would sometimes pause at his desk in the midst of the weightiest matters in order to write a charming letter of encouragement or of congratulation to a youthful acquaintance: from him came many kindnesses of which the world knew nothing. In himself he preserved until the end a certain element of

spiritual boyishness, allied closely with his eager zest for new knowledge and fresh experiences.

All his doings were marked by thoroughness and attention to detail. He left nothing to chance that could be controlled. Important ceremonies were always rehearsed *in situ*, any absent participant being represented by an understudy. Speeches on formal occasions were carefully cut to length. Sometimes the restrictions smacked of severity, but it was rarely possible to secure any remission. I recall that at the Smuts Rectorial Banquet, given in the United College Hall on October 17th, 1934, I was charged with the task of delivering the toast of " The Honorary Graduates." These were six in number including General Smuts himself, a highly-placed nobleman of the royal blood, an overseas Prime Minister, a member of the Cabinet, a Scots Lord, and an eminent scientist. The instruction was to say something apposite about each, and to lighten the proceedings with a telling anecdote—time allowed, five minutes, extended very reluctantly, after repeated expostulation, to seven ! Then, when it was all over, came a graceful note of appreciation and thanks.

Irvine's capacity for work was amazing. He never spared himself in the interests of any cause that he had at heart. It was next to impossible to persuade him to relax, even after the serious illness that struck him in 1951. To his close friends it was clear that he would die in harness, expending his last energies in the service of the University for which he held a deep and abiding love, tinged so often with a romantic and mystical quality. He presided at a prolonged meeting of the University Court on June 10th, 1952, and died two days later. His death ended an epoch; but that epoch will live for all time in the history of St Andrews University.

In 1950 Irvine wrote: " I find myself—a twentieth-century scientist—gazing across the chasm of five hundred years to a strange remote world and am conscious afresh of a feeling which never entirely escapes me that, as the thirty-fourth Principal of St. Salvator's College, I am privileged to share in the inheritance of a solemn trust; at once I am brought face to face with the question if the duty committed to that long succession of Masters has been faithfully discharged." The answer is clear to those who knew him; it will be even clearer to posterity.

His brother Principal, Sir Hector Hetherington, of Glasgow University, wrote of him: " Sir James Irvine will not be forgotten as long as the University of St. Andrews endures. He was its Principal for more than thirty years; he is now one of the commanding figures of its long history. To him, far more than to any other, the University owes the remarkable enlargement of its academic resources and the seemly beauty of its material estate. He loved St. Andrews with all the strength of an eager and generous heart, and gave to it the full service of his powers.

" And those powers were great. He had come, early in life, to high distinction in his chosen field of chemistry. Maybe it was part of the secret of his long enduring energy and freshness of mind that he never ceased to be a scientist. But as well he loved books and letters of all kinds; he had a quick imagination and an instructed pleasure in painting and architecture; he was a great traveller and a delightful companion.

" He could meet all sorts of people on the level of their own pursuits, and in turn engage their interest in his. So he made friends for himself and for his University, and for many other good causes. He was able to communicate to others—notably, for example, to his friend, Mr. E. S. Harkness—the visions which possessed his own mind; and, when thereby he had won the means of action, he spent with admirable economy and effect.

" Through St. Andrews, through the Universities Entrance Board, through the Carnegie Universities Trust, he influenced strongly the whole course of university and secondary school education in Scotland—and farther afield as well. He had close associations with many leaders both of thought and of affairs—he had an important share in making and administering enterprises like the Pilgrim Trust and the Commonwealth Fund Fellowships. And characteristically, in recent years, he had turned to constant and unsparing service for the new universities of the Commonwealth overseas. There, too, he will be remembered.

" It were easy to catalogue James Irvine's deeds and achievements, though the list would be long. It points to some elements in the man which derived from his essential being, to his quite unshakable industry—in all the many years of meetings, I never knew him otherwise than perfectly prepared, armed at every point—to his skill and persuasiveness in discussion, to his great powers of orderly and consistent administration. It were harder to describe the inward man—the scientist at odds sometimes with the impulses of the artist, the dreamer instant in action, well able, if need be, to be ruthless, ambitious yet controlled by the purposes and values to which he had given his allegiance, and withal of a tender heart. For myself, I think of him always as host and friend and counsellor, in his own home, which was the centre of all he did. It was a home of great beauty and of happiness unclouded until the war brought the heaviest

of sorrows. Thereafter, for him and for Lady Irvine, the brightness of the day had passed. Life could never again be what it had been; and advancing years brought some measure of bodily disability. But all was borne with the noblest courage; there was no faltering in duty or in affection. We who loved them give thanks for a life full of action and of service, for a home which felt the best that mortal man can know, for a splendid achievement, and for a quiet end."

Researches in Carbohydrate Chemistry

Irvine's outlook in science was essentially that of a pioneer blazing new trails and it so happened that the circumstances at St. Andrews when he began research work were such that he could give full play to his great powers. Thomas Purdie had published in 1899 an account of his work with Pitkeathly on the alkylation of alcoholic hydroxyl groups by the use of silver oxide and an alkyl iodide, and Irvine's first paper, also in 1899, dealt with the rotatory powers of the optically active methoxy- and ethoxy-propionic acids prepared from lactic acid, a subject

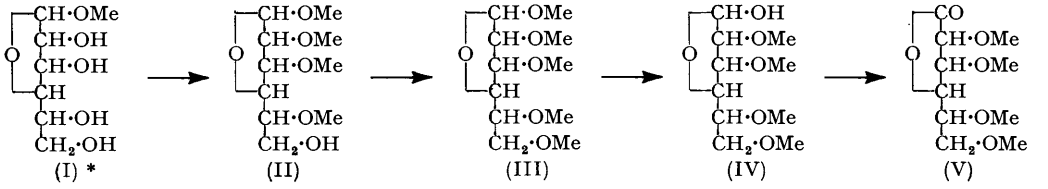
$$HO{\cdot}CHMe{\cdot}CO_2H \xrightarrow[MeI]{Ag_2O} MeO{\cdot}CHMe{\cdot}CO_2Me$$

to which he returned later (1906) when he used the methylation procedure to obtain proof of the efficacy of a resolution of (±)-lactic acid by way of the morphine salt. Irvine quickly realized the implications of Purdie's discovery and while still working for his doctorate at Leipzig he formulated a scheme of research by which the new technique could be used to attack structural problems in the field of carbohydrate chemistry. The significance of Irvine's contributions to this subject can be gauged by recalling the position reached at the time when he began his work. The importance of the carbohydrate group was recognized by both chemists and biologists, and spectacular advances in the chemical side had been made by Emil Fischer during the closing years of the nineteenth century. Despite his genius, however, many fundamental structural problems remained unsolved and suitable methods of investigation were not available. Fischer was turning his attention to other topics, and it appeared that for the time being a limit had been reached in structural work on the carbohydrate group. It was Irvine's great achievement to see that Purdie's alkylation process provided a new technique which could be applied in structural work in all branches of sugar chemistry. Indeed, so powerful and far-reaching has the methylation method proved to be that its usefulness is by no means exhausted after half a century's exploitation by workers in chemical schools in all parts of the world. When Purdie and Irvine first used the reaction, little was known with certainty of the detailed structure of the simple sugars, and still less about the disaccharides and polysaccharides. Irvine realized that the transformation into stable methyl ethers of the reactive hydroxyl groups present in the sugars provided a method by which the next stage in the development of carbohydrate chemistry could be initiated, and he indicated how the procedure could be used to determine the nature and position of the linkages in the disaccharides and polysaccharides.

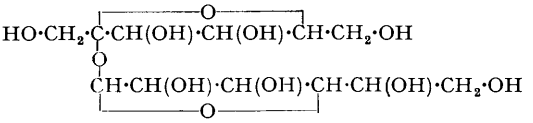
Such a programme could not be carried through until an adequate number of reference compounds became available, and from 1900 onwards he undertook a systematic study of the fully and partly methylated derivatives of the sugars. Purdie and he reported on the alkylation of sugars at the Belfast meeting of the British Association for the Advancement of Science in 1902, and at the following meeting in 1903 they contributed a note on applications of the method to the disaccharides. Much of the early work was concerned with the methylation of the methyl glycosides of the sugars, in which the highly reactive reducing group is protected. The solubilities of the unsubstituted reducing sugars in non-aqueous solutions are unfavourable and in such cases the early stages of methylation had to be carried out in the presence of water. In these circumstances considerable oxidative degradation took place, but this could be avoided by starting with the methyl glycosides. For instance methylation of α-methyl glucoside (I) in methyl alcoholic solution gave a methyl trimethylglucoside (II) which on further methylation in methyl iodide was transformed into α-methyl tetramethylglucoside (III). This on hydrolysis yielded the important crystalline reference substance tetramethylglucose (IV), the properties of which were closely studied. β-Methyl tetramethylglucoside was in a similar way prepared from β-methyl glucoside, and this substance was shown to be identical with a crystalline compound obtained by the direct alkylation of tetramethylglucose. From tetramethylglucose the corresponding tetramethylgluconolactone (V) was obtained on oxidation, and this group of transformations provided the strongest experimental evidence then available of the correctness of Fischer's formulation of the methyl glucosides.

The methods applied to the preparation of alkylated glucose derivatives were used for the

production of similar compounds from other sugars. These included α- and β-methyl tetramethylgalactosides and tetramethylgalactose; also α- and β-methyl tetramethylmannosides and tetramethylmannose. Workers at St. Andrews continued the story with investigations on the methylated derivatives of an aldopentose (arabinose) and a methylpentose (rhamnose). These sugars behave similarly to glucose, but in these early days considerable difficulties were encountered in the methylation of fructose. It was found, however, that a crystalline tetramethylfructose could be isolated, and many years later (1922) it was shown that crystalline tetramethylfructose could be obtained in good yield by methylating the β-methyl fructoside described by C. S. Hudson.

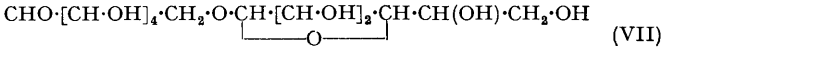


The methylated derivatives of sucrose and maltose were chosen as examples of the application of the methylation process to non-reducing and reducing disaccharides, respectively. Methylation of sucrose was first carried out in aqueous methanol, then in methanol, and finally in methyl iodide. Octamethylsucrose was thereby obtained, and this substance gave on hydrolysis a mixture of tetramethylfructose and tetramethylglucose, from which the latter was separated in a crystalline condition. The structure of the fructose portion remained a mystery for many years, but the work was of special importance in that it provided experimental proof of the correctness of Fischer's formula (VI) for sucrose in so far as the glucose half is concerned.



(VI) Fischer's formula for sucrose.

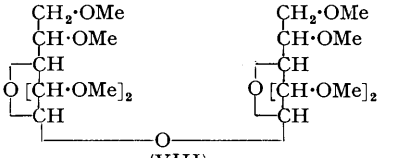
The reducing group present in maltose introduced difficulties, and methylation of the free sugar by Purdie's reagents could not be effected without oxidation of the aldehydic group. The methylated derivative gave, on hydrolysis, a mixture of products, amongst which was crystalline tetramethylglucose. Now Fischer had suggested that the mode of linkage of the glucose residues in maltose might be either of acetal or of glucosidic type. In the latter case the molecule of maltose could be represented by (VII). Whether the linkage is glucosidic or acetal in type



(VII)

the potential aldehyde group would undergo oxidation. On the other hand, the second glucose residue would appear (after alkylation and hydrolysis) as pentamethylglucose in the case of an acetal linkage, or as tetramethylglucose if the linkage is glucosidic. It followed, therefore, that maltose must contain the glucosidic type of linkage.

Another interesting development in the disaccharide field came with the synthesis of a non-reducing disaccharide by the condensation of two molecules of tetramethylglucose in a non-aqueous solvent under the catalytic influence of hydrogen chloride. The material so obtained was probably a mixture of the three stereoisomerides (αα, ββ, and αβ varieties) which can be represented by the formula (VIII). It was the first recorded instance of the synthesis of a derivative of a non-reducing disaccharide.



(VIII)

* The ring structures shown here and elsewhere in this notice are those depicted in the original publications. Since that time it has been ascertained that the stable forms of the sugars contain 1 : 5- instead of 1 : 4-oxide rings.

The methylation procedure was employed also in investigations into the structure of many sugar derivatives. An early example of this was a proof of the structure of the naturally occurring glucoside salicin. This gave on methylation a crystalline pentamethyl derivative (IX), hydrolysis of which, unfortunately, yielded only intractable resinous materials. Nevertheless, the desired proof of structure was obtained by synthesis. Saligenin and tetramethylglucose were heated in benzene containing hydrogen chloride, and the resulting syrupy glucosidic condensation product was methylated, giving the same crystalline pentamethylsalicin which was obtained from the natural product. Salicin, therefore, is structurally similar to the methyl glucosides obtained by condensing a sugar with methyl alcohol.

$$MeO{\cdot}CH_2{\cdot}C_6H_4{\cdot}O{\cdot}\underbrace{CH{\cdot}[CHOMe]_2{\cdot}CH}_{O}{\cdot}CH(OMe){\cdot}CH_2{\cdot}OMe$$

(IX) Pentamethylsalicin.

Compounds of sugars such as anilides and oximes had long been considered to be derived from the aldehydic form of the sugar, but a study of the anilide (X) obtained from tetramethylglucose showed that it exists in two forms and must possess a ring structure analogous to that of the methyl glucosides.

$$MeO{\cdot}CH_2{\cdot}CH(OMe){\cdot}\underbrace{CH{\cdot}[CH{\cdot}OMe]_2{\cdot}CH}_{O}{\cdot}NHPh \qquad (X)$$

Similar conclusions were reached concerning glucose oxime which, on methylation, gave tetramethylglucose oxime methyl ether (XI).

$$MeO{\cdot}CH_2{\cdot}CH(OMe){\cdot}\underbrace{CH{\cdot}[CH{\cdot}OMe]_2{\cdot}CH}_{O}{\cdot}NH{\cdot}OMe \qquad (XI)$$

At a very early stage Irvine realized the importance of the partially methylated monosaccharides as reference compounds which would be required in the course of work on the complex sugars. Various methods were used to effect syntheses by which methyl groups were established in known positions in the sugar molecule, and the quest thus started is by no means at an end, even after 50 years of endeavour on the part of many groups of chemists. Methylation of benzylidene and *iso*propylidene derivatives of sugars containing one or more free hydroxyl groups, followed by removal of the benzaldehyde or acetone residues, provided a practicable route, and the results obtained up to 1911 were summarized by Irvine in the following table, which is taken *verbatim* from the " Memorial Volume of Scientific Papers," published in connexion with the celebration of the Five Hundredth Anniversary of the founding of the University of St. Andrews.

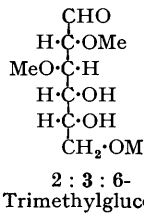
Condensed sugar derivative	No. of methoxyl groups introduced	Groups removed by hydrolysis	Methylated sugar derivative
Glucose diacetone	1	2 Mols. acetone	Monomethyl glucose
Benzylidene-α-methyl glucoside	2	Methyl alcohol and benzaldehyde	Dimethyl glucose
Glucose monoacetone	3	1 Mol. acetone	Trimethyl glucose
Fructose diacetone	1	2 Mols. acetone	Monomethyl fructose
Rhamnose monoacetone	2	1 Mol. acetone	Dimethyl rhamnose
Mannitol monoacetone	4	1 Mol. acetone	Tetramethyl mannitol
Mannitol diacetone	2	2 Mols. acetone	Dimethyl mannitol
Glycerol monoacetone	1	1 Mol. acetone	Monomethyl glycerol

These investigations involved detailed studies of the acetone derivatives of the sugars, and although much was learned in this difficult field, in many instances exact structural formulæ could not be assigned until the nature of the ring systems present respectively in the stable and labile forms of the sugars became known in later years. It is to be remembered that Irvine was very early in the new field opened up by Fischer's discovery of the reactive "γ"-methyl glucoside; and the methylation of this material, and of analogous "γ"-methyl glycosides prepared from other aldoses and ketoses was studied in the St. Andrews laboratories.

Another important problem in the monosaccharide group investigated by Irvine was the constitution of natural chitosamine (D-glucosamine). This work is presented in a group of papers published before and after the 1914—1918 war. Besides studying the properties of derivatives such as benzylidene and salicylidene methyl glucosamine, he endeavoured to obtain evidence concerning the stereochemical configuration of the $C_{(2)}$-amino-group. Conflicting

opinions were held as to whether the substance was a derivative of glucose or mannose, and Irvine showed that glucosamine could be transformed at will into glucose or mannose. The former is obtained from D-glucosamine hydrochloride *via* the methyl 2-amino-2-deoxyglucoside hydrochloride, which yields a dimethylamino-derivative. This loses the substituted amino-group when heated with barium hydroxide, and the product on further methylation yields methyl tetramethylglucoside. The second series of reactions proceeds *via* benzylidene-2-amino-2-deoxyglucoside methyl hydrochloride, which gives a benzylidenehexose, and this, on hydrolysis, gives rise to D-mannose. Walden inversion was held to be more likely in the second series of transformations, and Irvine inclined to the view that chitosamine was in fact D-glucosamine, but the decision had to be left open until many years later when unequivocal proof of the glucosamine structure was obtained by entirely novel methods of enquiry.

It had been clear from the beginning of the carbohydrate work at St. Andrews that the final goal was the application of the new methods to structural studies in the fields of the oligosaccharides and the polysaccharides. The Purdie method of alkylation was both difficult and tedious when applied to materials like starch and cellulose, and W. S. Denham, working in Irvine's laboratory, found that methyl sulphate and sodium hydroxide could be used as methylating agents in such cases. He obtained a partially methylated derivative of cellulose from which he isolated, after hydrolysis, a trimethylglucose which carried the methyl groups at positions 2, 3, and 6. This 2 : 3 : 6-trimethylglucose soon proved to be an all-important reference substance.



2 : 3 : 6-Trimethylglucose.

At about the same time (1912—1913), W. N. Haworth (later Sir Norman Haworth, F.R.S.), then a member of the staff at St. Andrews, became interested in carbohydrate chemistry. He showed that methyl sulphate and alkali could be used also for methylating reducing sugars, the reactive reducing group being transformed smoothly and without decomposition into the methyl glycoside. The new procedure was rapid and convenient, and was applied by Haworth and his St. Andrews collaborators to sucrose, lactose, maltose, cellobiose, and raffinose.

Irvine, at this point, tended to concentrate more on the polysaccharide group, and he began, with Miss E. S. Steele, a series of studies on the chemistry of inulin. The methylated derivative was prepared and hydrolysed, and the trimethylfructose thereby obtained was recognized as a derivative of "γ"-fructose. Investigations were undertaken also into the structure of cellulose, in the course of which the quantitative transformation of the polysaccharide, *via* its triacetyl derivative, into methyl glucoside was effected. Further studies of trimethylcellulose, which had first been prepared by W. S. Denham, were made, and it was shown that this substance gives rise almost quantitatively on hydrolysis to 2 : 3 : 6-trimethylglucose. It followed that cellulose itself must be composed almost exclusively of residues of glucose in which the hydroxyl groups at $C_{(2)}$, $C_{(3)}$, and $C_{(6)}$ were not involved in the linkages between the glucose molecules. Pioneering work was carried out on the structure of starch, in the course of which starch and certain of its degradation products were methylated and the methyl derivatives subjected to hydrolysis. Again 2 : 3 : 6-trimethylglucose was identified as the main product, and, in view of the close relationship between starch and maltose, these studies involved a reconsideration of the structure of this disaccharide, the methylated derivative of which was at that time thought to yield 2 : 3 : 4-trimethylglucose on hydrolysis. Proof was obtained that octamethylmaltose yields, in fact, 2 : 3 : 6-trimethylglucose, and the isolation of the latter sugar from trimethylstarch became readily understandable.

At this period also (1923 onwards), the difficult question of the nature of the ring systems present in the normal and "γ"-forms of the sugars was resolved, and it became possible to ascribe much more definite structural formulæ to the various simple and complex sugars and their derivatives. Work carried out in St. Andrews demonstrated the presence of the 1 : 5 ("amylene oxide")-ring structure in the aldopentose sugar xylose (Hirst and Purves), and proof of the six-membered oxide ring structure in derivatives of normal glucose soon followed. The quest was eagerly pursued in St. Andrews and in other laboratories, notably by Sir Norman Haworth's school at Birmingham, and by 1927 generalizations concerning ring structures had become possible.

Irvine had always been specially interested in sucrose, and he devoted much attention over a period of several years to attempted syntheses of this important sugar. With J. W. H. Oldham and other collaborators he examined with meticulous thoroughness the condensation of glucose with derivatives of fructofuranose, but in no case could any trace of sucrose be detected, a conclusion which has been amply confirmed by subsequent investigators. Pictet's claim to

have synthesized sucrose could not be substantiated, but the St. Andrews workers succeeded in synthesizing an isomeride which differed from sucrose in the stereochemical arrangement of the glycosidic links.

It was inevitable that Irvine had progressively less time to devote to chemical research once he had taken over the onerous duties of Principal and Vice-Chancellor in 1921. Nevertheless, his interest in carbohydrate chemistry never diminished, and much important work in this field continued to be published from the St. Andrews laboratories, notably by G. J. Robertson, J. W. H. Oldham, A. Hynd and their collaborators. It was also characteristic of Irvine that only a few days before his death he was busy propounding long-term schemes of research on possible developments of carbohydrate derivatives for use in chemotherapy.

Irvine's pioneering activities covered a wide range of problems in carbohydrate chemistry. His work throughout was characterized by originality of thought and clearness of vision. His scientific publications reveal the elegance and forcefulness of style which is evident in all his writings. The ideas he put forward have been singularly fruitful and the achievements of the small band of research workers who began their studies in St. Andrews under his leadership half a century ago have instigated chemists in all parts of the world to carry out the ever-increasing volume of work which has built up the imposing edifice of carbohydrate chemistry as we know it to-day.

Grateful acknowledgments are due to Professor E. L. Hirst, F.R.S., for the section of this notice on researches in carbohydrate chemistry; to Sir Hector Hetherington for his tribute, of which the first draft appeared in the *Glasgow Herald* of June 13th, 1952; and to Dr. Ettie S. Steele for help with a bibliography.

JOHN READ.

LAWRENCE JOHN LERMIT.

1916—1953.

LAWRENCE JOHN LERMIT was born at Stafford on September 27th, 1916. He was educated at Canford School and proceeded thence to the Imperial College of Science, London, where he took his B.Sc. with 2nd Class Honours in chemistry, botany being his subsidiary subject. He was also awarded A.R.C.S.

His post-graduate work under Professor R. P. Linstead and the late Professor G. A. R. Kon was interrupted by the war. He took up a post at the Ministry of Supply Research Establishment, Sutton Oak, in 1941 and, after a brief sojourn with Messrs. F. W. Berk and Sons, Stratford, from 1947 to 1948, rejoined the Ministry of Supply at the Chemical Defence Experimental Establishment, Porton, in the latter year. Here he worked until his untimely death on July 24th, 1953. He was promoted Senior Scientific Officer in July, 1952.

One could not wish for a more loyal and devoted colleague. His knowledge of organic chemistry, in which subject he was completely wrapped up, was quite encyclopædic and was of the greatest assistance to all of us here. John Lermit was a most diffident and unobtrusive individual. He never enjoyed the best of health and underwent a major operation in July, 1951. He was particularly keen on the practical side of his subject and made a notable contribution to our knowledge during the relatively short time he was with us. Outside his official work, he took a great interest in the chemistry of drugs and perfumery. He was also a keen gardener. He is survived by his wife and two sons and will be held in affectionate remembrance by all his colleagues in the Establishment.

A. H. FORD-MOORE.

JAMES PETTIGREW OGILVIE.

1881—1953.

JAMES PETTIGREW OGILVIE died on September 13th, 1953. He was born in Greenock, Scotland, on July 11th, 1881, being the third son of Thomas R. Ogilvie, a well-known sugar refiner. He was educated at Armadale School, Melbourne, Australia, and was for a time student-assistant at the Government Agriculture Laboratory, Melbourne. In 1898 he proceeded to Finsbury Technical College (City and Guilds of London Institute), where he studied until 1901.

In 1902 he became assistant to Newlands Bros., authors of the textbook " Sugar," and was for a time in practice on his own account. In 1908 he joined the staff of the *International Sugar Journal*, and in 1910 became the Technical Editor of that publication, a position he held until his death. He contributed a number of papers relating to the manufacture of sugar, and the analysis of sugar factory and refinery products, to that *Journal* and to the *Journal of the Society of Chemical Industry*. He also contributed the section on Sugars, Starches, and Gums of the *Annual Reports on the Progress of Applied Chemistry*, on several occasions (1918, 1919, 1920, and 1921). In 1913 he translated Harloff and Schmidt's " Plantation White Sugar " from the Dutch.

Ogilvie was elected an Associate of the Institute of Chemistry in 1919, and became a Fellow in 1924. Since 1912, he had been a Fellow of the Chemical Society to whom he presented a number of valuable books on sugar chemistry, and he worked as an abstractor in the sugar section to the *Journal of the Society of Chemical Industry*, and later to *British Abstracts* until 1950. For many years he had been Examiner in Sugar Manufacture to the City and Guilds of London Institute. He was associated for many years with a successful business supplying machinery, chemical preparations, and accessories to the sugar industry.

P. V. MOYES.