PROFESSOR WALTER T. J. MORGAN

This issue of *Carbohydrate Research* is dedicated to Walter Thomas James Morgan in recognition of his outstanding pioneering contributions to the immunochemistry of carbohydrates.

Walter Morgan was born in Ilford, London on October 5th, 1900. He attended Raine's Foundation School, London, and during his schooldays he developed an interest in chemistry which he retains to this day. Because of the national emergency of the 1914–1918 war, he decided to leave school at the age of sixteen to seek employment in a government factory for the production of synthetic phenol, a key chemical in the war effort. He found this an interesting and profitable experience but shortly before his eighteenth birthday he enlisted in the Navy and was posted to the Royal Naval Experimental Station, London. On demobilisation in 1919 he enrolled as a student in London University and, after graduating with a B.Sc., he obtained a position in an industrial laboratory but immediately set about working for a higher degree. He was given permission to occupy a bench in the local technical college during the evenings and there carried out his own research on amino acid esters for which he was awarded an M.Sc. degree in 1925. Here fate took a hand as one of the examiners of his thesis was Professor Arthur Harden, who was head of the biochemical department at the Lister Institute of Preventive Medicine, a post-graduate school of London University. Obviously impressed by the candidate, he recommended him to apply for a Grocer's Company Research studentship tenable at the Lister Institute. Walter Morgan accepted this invitation with alacrity and the award of the studentship in 1925 was the start of his long research career in the biochemistry of carbohydrates.

Walter Morgan's early years at the Lister Institute were spent in the laboratory of Dr. (later Professor) Robert Robinson working on the structures of hexose phosphates and other sugar esters that were of considerable interest at that time as the products of controlled yeast fermentation. In 1926 he attended a course of quantitative organic microanalysis in the University of Graz, Austria, under the tutelage of Professor F. Pregl and on his return he set up microanalytical techniques at the Lister Institute, probably the first laboratory in the United Kingdom to put these procedures into use. His Ph.D. degree was awarded in 1927 by the University of London and, in the same year, he was elected to a Beit Memorial Research Fellowship which enabled him to continue for the next two years with his researches on carbohydrate metabolism at the Lister Institute. In 1929 he was appointed as Biochemist to the Lister Institute's Serum and Vaccine Department which was housed outside London in Elstree, Hertfordshire. The rural surroundings were attractive but the laboratories afforded few facilities for serious biochemical research, even by the standards of the day. He therefore decided to take this

opportunity to learn some immunology and joined in the day-to-day problems associated with the production and testing of antisera and bacterial toxins. The occasion of the International Physiological congress in Boston in 1929 enabled him to visit several industrial and state-run toxin and serum laboratories in the U.S.A. and Canada and to meet for the first time a number of distinguished workers in the field of bacterial antigens, including Walter Goebel and Michael Heidelberger. These contacts, together with his experiences of the practical problems connected with the production of anti-bacterial and anti-toxic sera, shaped the research that he was to carry out for the next decade. His aim was to prepare bacterial antigens in a form more suitable to prophylactic inoculation than the crude bacterial suspensions employed at that time. As early as 1931, he described highly purified specific polysaccharides from several bacteria of the dysentery-typhoid group. This was followed by the isolation of the whole "O"-somatic antigen from a number of pathogens, work which led to his seminal discovery that the complex is composed of three parts, a polysaccharide which carries the serological species specificity, a "conjugated protein" which confers immunogenicity on the haptenic polysaccharide, and a lipid component. In the course of these investigations, it became apparent that new procedures were needed for measuring the amino sugars which, as he found, are important components of some of the bacterial antigens. With his colleague L. A. Elson, he embarked upon the task of developing a simple colorimetric method for the quantitative measurement of hexosamines and *N*-acetylhexosamines. The results embodied in papers published in 1933 and 1934 provided methods that, with only slight modifications, remained in use for nearly four decades. Despite the success of this excursion into analytical methodology, Walter Morgan did not find the experience a rewarding one and resolved in future to leave the development of methods to others more liberally endowed with the type of patience required for this kind of endeavour.

By 1936 Walter Morgan considered it was necessary to refurbish his chemical skills and the award of a Rockefeller Foundation Fellowship enabled him to work in the distinguished School of Organic Chemistry at the Eidgenössiche Technische Hochschule in Zürich for about three semesters. With Professor Tadeusz Reichstein, he was engaged on problems of structure and synthesis of certain analogues of ascorbic acid and for this work gained the Degree of Doctor of Science (Tech.), Zürich, in 1938. On his return to England, he was called almost immediately to take up a Readership in Biochemistry at the Lister Institute in London where with his colleague S. M. Partridge he continued his investigations on bacterial antigens until shortly after the outbreak of World War II in 1939. Work with relatively large-scale cultures of pathogens soon became impractical under wartime conditions in London and his researches on the bacterial antigens stopped at that time and were never resumed. This pioneering work had, nevertheless, firmly established certain fundamental ideas on the composition and general macromolecular structures of the "O" somatic antigens of Gram-negative bacteria and formed a sound basis for successors, such as Otto Westphal and his colleagues in Freiburg,

Germany, who were to expand this field in such an exciting way in the years following the war.

With the collapse of the work on the bacterial antigens, Walter Morgan turned his attention to another aspect of immunochemistry, namely, the human blood group antigens which were of obvious importance in the rapidly developing field of blood transfusion. Knowledge of the chemistry of the antigens associated with the classical ABO blood-group system was then extremely fragmentary and once again he was to make outstanding fundamental observations in his chosen subject. From the outset his aim was to correlate genetic status with the chemical structures found in the blood group active materials and he realised the necessity of using materials from single individuals and of not pooling substances from several donors. For the same reasons he considered it imperative to use human materials rather than the more abundant substances of animal origin which have specificities related to the human-blood characters. With Ruth van Heyningen, he demonstrated that human ovarian cyst fluids were a potent source of secreted, water-soluble, blood-group active substances and these cysts provided the major starting materials for those investigating the biochemistry of the ABO and Lewis blood groups at the Lister Institute, and elsewhere, for the next 25 years. In the 1950s, with colleagues Aminoff, Annison, Gibbons, Pusztai, and Watkins, he isolated highly purified preparations of A, B, H, Le^a and HLe^b substances and characterised them in terms of their chemical composition, physical and immunological properties. The substances were identified as carbohydrate–protein complexes, at that time called mucopolysaccharides and now known to correspond to the major epithelial glycoproteins present in mucus secretions. With David Aminoff, he showed in 1948 for the first time that *N*-acetylgalactosamine is a constituent of these glycoproteins and subsequently this sugar was found at the Lister Institute to play a vital role in blood group A specificity and by others to be involved in the carbohydrate–peptide linkage in all epithelial-type blood group active glycoproteins. In the 1950s with his colleague Winifred Watkins, he established by indirect methods of serological and enzymic inhibition that specificity was associated with the carbohydrate component of the glycoproteins and that for each blood-group determinant one sugar, later to be termed the immunodominant sugar, was more important than the others for the antigenic properties of the molecules. One method they introduced at this time was the inhibition of blood-group specific plant agglutinins, later called lectins, with simple monosaccharides. The experiments demonstrated for the first time the carbohydrate specificity of the plant reagents and thus heralded the multiplicity of uses to which lectins were subsequently to be put in structural studies on glycoconjugates and in cellular immunology. The first use of exo-glycosidases to sequentially degrade the oligosaccharide chains of the glycoproteins gave clues as to the order of the sugars in the blood-group determinants. However, Walter Morgan's firm grounding in chemistry made him aware that, despite the information gained by means of the indirect approaches, the final proof of the structures could only be obtained through the isolation and characteri-

sation of blood-group active fragments from the glycoproteins. Therefore, with colleagues Côté, Cheese, Painter, Donald, Rege, Marr and others, he set about the systematic isolation and structural identification, by standard methods of carbohydrate chemistry, of the antigenic groupings associated with the *ABO*, *H* and *Lewis* blood group systems. With masterly timing, the fifth and last of the specificities, namely Le^b, was characterised shortly before he retired in 1968 from the Chair of Biochemistry at the Lister Institute to which he had been appointed in 1951. The identification of these five oligosaccharide determinants constitutes a classical piece of carbohydrate immunochemistry and enabled many fundamental questions to be answered concerning the interrelationships between the *ABO* and *Lewis* blood group genes.

As is perhaps not unexpected for someone who had been such a dedicated research worker, official retirement did not mean an end to Walter Morgan's scientific career. He was succeeded as head of the department by Winifred Watkins who invited him to continue working in the laboratory. Free from administrative responsibilities, he spent an enjoyable and successful period investigating, with a few co-workers, another water-soluble antigen, the P_1 antigen in the blood group P system which is expressed on glycoproteins occurring in hydatid-cyst fluids. However, by 1972, the Lister Institute was in serious financial difficulties and he was recalled from retirement and asked to take over as Director. He devoted much time and energy to schemes devised with the hope of saving this venerable institution which had been such a haven for medical research workers since the beginning of the century and had seen so many distinguished scientists passing through its doors. However, the financial problems could not be solved and, when closure became inevitable, he turned his efforts to securing other placements for the few remaining staff. It was a great sadness for him, in 1975, to have to preside over the closure of the Institute which had been his scientific home for nearly fifty years. His interest in immunochemistry had not diminished, however, and when his task was complete he joined, as a guest worker, Winifred Watkins' group which had moved to the Medical Research Council's Clinical Research Centre in Harrow. In the last ten years, he has been involved with others in that laboratory on the elucidation of the structure of the human blood-group Sd^a antigen, a blood group determinant which is also carried on Tamm–Horsfall urinary glycoprotein. He still very much enjoys working at the bench and takes a keen interest in the activities of the research group around him.

Throughout the course of his long research career, Walter Morgan served on many Government Advisory Committees, University of London Boards of Study, and on the Medical Research Council. His achievements have brought him many honours which include election to the Royal Society in 1949, service on the Council 1956–58 and as a Vice President of the Society under Lord Florey from 1961 to 1964, an honorary MD degree from Basel University, an Honorary D.Sc. degree from the University of Michigan, the Conway Evans Prize from the Royal Society and Royal College of Physicians, London, the Karl Landsteiner award of the

American Association of Blood Banks, the prestigious Paul Ehrlich and Ludwig Darmstädter gold medal and prize of the Paul Ehrlich foundation, Germany, and the Royal Medal of the Royal Society. He was awarded a CBE in 1959 and more recently elected as an Honorary fellow of the Royal College of Physicians, London.

Throughout his scientific career, Walter Morgan's work has been characterised by originality combined with the application of rigorous chemical techniques to biological problems, a willingness to step out into the unknown and a tenacity of purpose. His pre-war training with limited facilities taught him the value of simple experimental procedures, and these lessons he has tried to inculcate into his students. As one who has always regarded it as a considerable privilege to be able to spend his working life in full time research, he has scant sympathy or patience with anyone granted this privilege who is less than complete in their dedication to their tasks. However, for those sharing his infectious enthusiasm, he is most generous with his time and support. His friends and colleagues who have contributed to this volume offer their affection, admiration, and respect and wish him many more years to continue with his scientific endeavours.

WINIFRED M. WATKINS