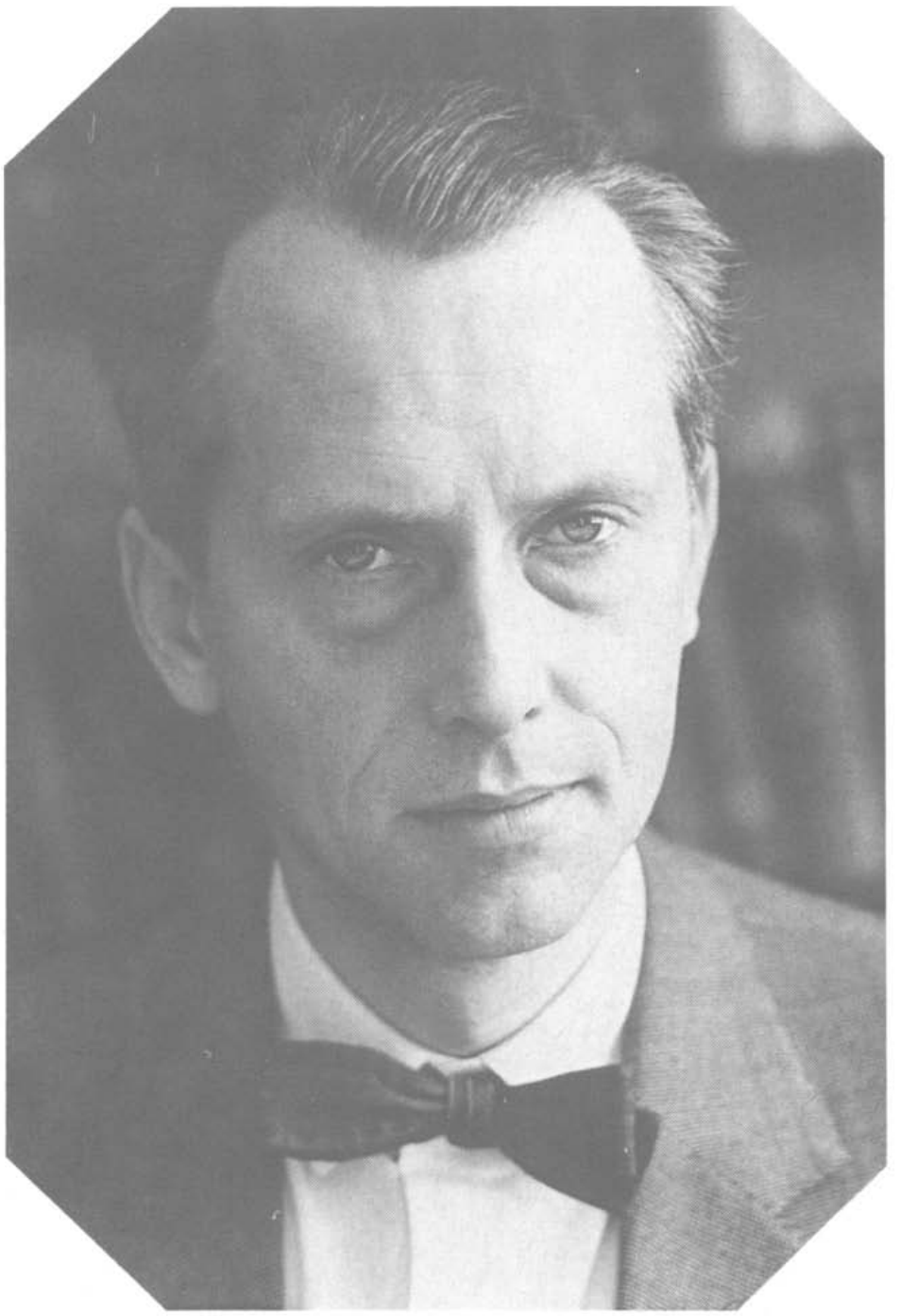

PROFESSOR BENGT LINDBERG

Bengt Lindberg, to whom this issue of *Carbohydrate Research* is dedicated, is well-known to carbohydrate chemists for his significant scientific contributions especially in the structural analysis of bacterial polysaccharides. We would like to honour him as a distinguished scientist and for his outstanding contributions to the development of carbohydrate chemistry.

Bengt Gustaf Lindberg was born in Stockholm on July 17, 1919 as the first of three children. His parents, Henry and Elsa (born Tengvall), soon found that their son was more interested in natural sciences than in law and administration which was the profession of his father. The young Lindberg studied at "Södra Latin", a well-known school in the southern part of Stockholm, from which he graduated in 1937 and then continued his education at "Stockholms Högskola" (nowadays the

University of Stockholm) where he studied chemistry, mathematics, and physics. After obtaining his B.Sc., he continued in organic chemistry and later defended his doctoral thesis "Studies on Glycosides, especially the α/β Transformation" in 1950. The next year he was appointed Docent and achieved the status of Professor in 1959.

Bengt Lindberg has had several academic positions. He was lecturer at the Royal Institute of Technology 1950–1955, Research Director of the Wood Chemistry Department at the Swedish Wood Research Institute 1955–1965, and Professor and Head of the Department of Organic Chemistry at the University of Stockholm 1965–1986. He became a member of the Royal Swedish Academy of Sciences in 1967 and served on its Nobel Committee for Chemistry 1974–1987.

At the beginning of his research career, Bengt Lindberg had Professor Holger Erdtman as his supervisor, who introduced him to natural product chemistry, a field which has never left his interest. He also became interested in carbohydrate chemistry and, throughout his career, this is the area where he has made his major scientific contributions. However, Lindberg's first scientific paper, "Bestimmung von cocarboxylase in blut", was published in 1939 before the carbohydrate period.

The earlier studies of carbohydrates dealt mainly with the action of strong acids on acetylated glycosides and α/β transformations aiming at the chemical synthesis of isomaltose, an investigation suggested by Professor Karl Myrbäck in 1942. This work led to the synthesis of β-isomaltose octa-acetate from α-gentiobiose octa-acetate by reaction with titanium tetrachloride in chloroform.

Lindberg's period at the Royal Institute of Technology was most productive (some 60 published papers). He lost no time in establishing himself as a natural products chemist of considerable potential, working mainly with compounds of low molecular weight. Many of these studies were related to natural compounds from algae and lichens. Other research areas involved quinone and hydroquinone chemistry.

During his time as Research Director in the Wood Chemistry Department at the Swedish Forest Products Research Laboratory, he maintained a special teaching position at the Wood Chemistry Department at the Royal Institute of Technology. In this period, Lindberg and his co-workers produced a long series of papers describing structural studies of wood polysaccharides. Other papers described the structural determination of various natural products, mainly of wood origin, and also the distribution of substituents in a series of cellulose derivatives. His early interest in synthesis was expressed in several papers devoted to synthetic carbohydrate chemistry. Other projects, as would be expected, dealt with problems directly related to cellulose technology. A considerable number of doctoral dissertations were associated with this highly successful period of research.

Lindberg was invited to take the Chair in Organic Chemistry at the University of Stockholm in 1965. Here, once again, he displayed his unusual talent for collecting, developing, and organizing individuals with various abilities and created what became known as the "Lindberg school" of carbohydrate chemistry, working with

methodology for, and structural elucidation of, a wide range of polysaccharides and also methodology for synthetic carbohydrate chemistry. Many individuals were involved in this venture and, in retrospect, their precise contributions to the large mass of results are not always easy to evaluate.

Since about 1970, Lindberg's major research activities in this school have been focussed on polysaccharide chemistry, starting with the simplification of methylation analysis, one of the major techniques for studying polysaccharide structures. This procedure is described in all textbooks in organic chemistry and on paper it looks very simple. However, the classical method, which involved separations, initially by high-vacuum distillation and later by chromatography, to obtain each component pure and quantify its proportion, was a formidable experimental task. Lindberg realized early on that the answer was to use new equipment then coming on the market, namely, instruments for gas chromatography and mass spectrometry. Taking advantage of the modified methylation technique first described by Hakomori and later elaborated by Conrad and Sandford, a streamlined procedure for methylation analysis was worked out based upon the separation and identification of partially methylated alditol acetates, with the first papers published in 1967. This analysis took at most a few days to perform, on milligram quantities of materials, instead of requiring the gram quantities of polysaccharide and months associated with the classical procedures. It represents an enormous simplification in structural polysaccharide work. The major paper describing this work, co-authored with Björndal, Hellerqvist, and Svensson, was published in 1970 in *Angewandte Chemie*, and has been featured as a *Current Contents Citation Classic*. In present-day papers, as often as not, the method is not even cited, having achieved the elevated status of "distinction by oblivion" and is now a natural part of a carbohydrate chemists's intellectual equipment. Other major innovations in chemical methods for polysaccharide analysis devised by the Lindberg group include the degradation of uronic acids by alkali, the chromic acid degradation, the sulphone degradation, modifications of the Smith degradation, the keto degradation, and also *N*-deacetylation and subsequent degradations.

Thus, armed with a whole new and streamlined arsenal of methods for the structural analysis of polysaccharides, it became possible for the Lindberg group to embark on a venture lasting more than a decade and a half in which the structures were determined for a wide range of polysaccharide antigens from cell walls and capsules of pathogenic bacteria and also some polysaccharides of industrial significance.

Many of the lipopolysaccharides of bacteria are polymers with regular structures, being built from repeating units. Starting with the cell-wall polysaccharides of the *Salmonella* bacteria, which were the first structures to which the new methods were applied, the research continued with structural studies of, *inter alia*, polysaccharides from *Klebsiella, Shigella, Streptococcus, Vibrio cholerae, Eubacterium, Haemophilus, Escherichia coli, Yersinia, Rhizobium,* and *Xanthomonas*. This work continues, with high-resolution ^{1}H- and ^{13}C-n.m.r. spectroscopy assuming increasing importance.

This research was carried out in close collaboration with bacteriologists and immunologists, and it has become possible to correlate structural elements to immunological properties. Once this correlation is established, the door is opened for the synthesis of artificial antigens for future use in improved diagnostics and vaccines.

The isolation of many new rare monosaccharide components from hydrolysates of these polysaccharides also raised challenging problems in synthesis. So also did the emerging need for oligosaccharide fragments, usually joined to linking arms suitable for attachment to proteins, in order to obtain artificial antigens for biological studies. Thus, the collaboration between scientists working on structural studies and synthesis has assumed increasing importance in the group over the years. On occasion, such as in the investigation of the active oligosaccharide fragment in plant phytoelicitors, chemical synthesis proved to be the only way to pinpoint the biologically active structure.

Lindberg has written many review articles and book chapters, and has dealt with nomenclature simplifications. In so doing, he has made a major contribution in bringing together and organizing large bodies of information, dealing with methods as well as structures. In this respect also, he has rendered his fellow scientists a major service.

Lindberg's research has resulted in a large number of doctoral degrees. During his time at the University of Stockholm alone, there were some 40 Ph.D. theses in the carbohydrate field. A number of his students both from this and the previous period are now active in leading industrial positions and as professors in academic institutions.

Lindberg's current publications list comprises some 390 papers, and continues to increase. He has received a number of awards for his scientific contributions, including the Norblad–Ekstrand Medal in 1956, the Oscar Carlsson Medal in 1978 from the Swedish Chemical Society, the Haworth Memorial Medal in 1981 from the Royal Society of Chemistry, the Hudson Award in 1983 from the American Chemical Society, and the Celcius Medal in 1985 from the Royal Scientific Society in Uppsala.

We congratulate Bengt Lindberg on his many achievements and wish him success in his continuing research ventures.

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