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The Whistler Center for Carbohydrate Research at Purdue University

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The Whistler Center for Carbohydrate Research is a unique academic institute dedicated to fundamental research and educational and service programs related to the commercial use of carbohydrates. The mission of the Whistler Center is to further the industrial utilization of carbohydrates through an increased understanding of their chemical, physical and biological properties (particularly those properties related to food, paper, petroleum recovery, biomedical and other practical applications), to serve the industries that produce carbohydrate products and those that use them, and to increase the number of scientists trained to work with carbohydrates.

Organization of the Whistler Center for Carbohydrate Research began in January 1986 with the arrival at Purdue University of its first Director, James N. BeMiller. The Center was established to meet a worldwide need for a greatly expanded fundamental research effort in carbohydrates. It was created by Purdue University because it was recognized by Philip E. Nelson (Head of the Department of Food Science) and Bernard J. Liska (Dean of the School of Agriculture) that the value of carbohydrates to the industries of the world and to human health and welfare was not reflected in the degree of either fundamental or applied carbohydrate research. Because approximately 70% of the dry weight of plants is made up of carbohydrates in a variety of forms, because at least 90% of this carbohydrate is in the form of polysaccharides, and because polysaccharides are, therefore, an enormous, annually renewable natural resource available to make value-added products, a primary focus of the Center is on polysaccharides and products derived therefrom. However, the faculty of the Center also recognise that carbohydrates have most important physiological and biochemical roles in animals (structural, nutritional, immunological,

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adhesive, energy metabolism, communication, etc.). Therefore, a carbohydrate or carbohydrate-related material may be investigated from a chemical, biochemical, physiological, and/or engineering perspective.

The basic philosophy of the Center is service, service provided through research, education, and information. The service provided can be summarized as follows:

Research Service. Multidisciplinary studies leading to an increased understanding of the physical, chemical, and biological properties of carbohydrates that are generally important in their practical applications.
Educational Service. Provision of undergraduate, graduate, post-doctoral, and continuing education programs in carbohydrate research and technology.
Information Service. Development of an information base on world-wide activities in carbohydrates, development of a database on carbohydrate properties, an annual conference on recent developments in carbohydrate research, and availability of center faculty as consultants.

Activities of the Whistler Center for Carbohydrate Research are described more clearly by the following specific objectives:

To conduct fundamental research that fulfills the mission of the Center.
To apply the rapidly expanding base of scientific knowledge and methodology to carbohydrate research.
To be an interdisciplinary resource of scientific and technical information and to provide advice to academic and industrial scientists and engineers and to policymakers (so that they can reach informed decisions on issues involving carbohydrate chemistry and biochemistry).
To serve as a communications bridge across industry, government, and university boundaries and to provide a forum where representatives from each sector can work together to their mutual benefit.
To provide a much-needed supply of scientists trained to work with and to understand the properties of carbohydrates through undergraduate, graduate, post-doctoral, and continuing education programs.
To conduct conferences, workshops, symposia, and progress review meetings.
To prepare reviews on carbohydrates and carbohydrate-containing molecules and products.
To establish a network of international contacts through exchanges of information and people.

Specific projects in each of these areas are developed with the help of an Industrial Consortium and Advisory Board. The establishment of the Industrial Advisory Board is a key feature of the Center because the Center faculty view themselves as partners with those who support and will benefit from its activities and who will eventually reduce fundamental knowledge to commercial application. In addition, the Center faculty believe that there can be a productive interaction between the Center and companies with a mutual interest in carbohydrates. Membership on the Advisory Board is limited and provided to those companies who pledge long-term support. The Board articulates research needs, reviews policies and directions, reviews project progress, evaluates proposals, and establishes objectives. As of June 1988, there were six Sustaining Members of the Industrial Consortium: Hershey Foods Corp., Kraft Inc., National Starch and Chemical Corp., The NutraSweet Co., RJR Nabisco (Nabisco Brands, Del Monte, Planters/Life Savers, R. J. Reynolds Tobacco) and the A. E. Staley Mfg Co.

Project support comes from a number of sources in addition to consortium members, including other industrial organizations, industry associations, state and federal governmental agencies, Purdue University, and Purdue University Agricultural Experiment Station.

As of January 1988, the second anniversary of the Whistler Center for Carbohydrate Research, the Center's staff consisted of three permanent full-time faculty, eight post-doctoral research associates, and three graduate students. In addition, there are at Purdue University a number of other faculty members whose research deals with carbohydrates and who wish to be associated with the Center; they are listed at the end of this article.

The Center is named in honor of Distinguished Professor Emeritus Roy L. Whistler, who joined the Purdue faculty in 1946, was named Hillenbrand Distinguished Professor in 1973, and was awarded an honorary degree by Purdue University in recognition of his contributions in 1985. His accomplishments in carbohydrate chemistry and biochemistry, primarily in the area of polysaccharide structure and function, had been recognized previously with a number of other awards, medals, dedications, and honors, viz., the Annual Research Award of the Purdue University Chapter of The Society of the Sigma Xi; the Claude S. Hudson Award of the Division of Carbohydrate Chemistry of the American Chemical Society; the Anselme Payen Award of the Division of Cellulose, Wood, and Fiber Chemistry of the American Chemical Society; the Award of Merit of the Japanese Society of Starch Science; the Alsberg-Schoch Award and the Osborne Medal of the American Association of

Cereal Chemists; the Saare Medal of the Association for Cereal Research (Arbeitsgemeinschaft Getreideforschung); and the Spencer Award of the Kansas City Section of the American Chemical Society. He has also been honored with a special issue of *Carbohydrate Research.*

He is a past-president of the American Association of Cereal Chemists, the American Institute of Chemists, and the International Carbohydrate Organization, and has served on the Boards of Directors of the American Chemical Society, the American Association of Cereal Chemists, and the American Institute of Chemists, and on the National Executive Committee of The Society of Sigma Xi.

Professor Whistler, who has given Purdue University international stature in carbohydrate chemistry, continues to direct an active laboratory. Post-doctoral Research Associates working with him are investigating new industrial gums, new bulking agents, new high-intensity sweeteners, and carbohydrate-based pharmaceuticals.

The Director of the Center is James N. BeMiller. Professor BeMiller began his association with carbohydrates and Professor Whistler as an undergraduate student at Purdue University. After earning his BSc degree in 1954, he became a Whistler graduate student and then a post-doctoral fellow. He left Purdue University in 1961 to become an Assistant Professor in the Department of Chemistry (later the Department of Chemistry and Biochemistry) at Southern Illinois University at Carbondale, where he was named Professor in 1968.

At SIUC, Dr BeMiller served as Chairman of the Department of Chemistry and Biochemistry and Dean of the College of Science. He was involved in the creation of the SIU School of Medicine and was named a Professor in that school in 1971. He later served as Chairman of the Department of Medical Biochemistry and as Assistant Dean for Curriculum in the School of Medicine. He returned to Purdue University in January 1986 as Professor and Director of the Whistler Center for Carbohydrate Research.

With Professor Whistler, he is the editor of several highly successful books, *Starch: Chemistry and Technology* (two editions), *Industrial Gums* (third edition in preparation), and *Methods in Carbohydrate Chemistry* (eight volumes have been published, three are in preparation).

Dr BeMiller is President of the American Institute of Chemists and the National Representative of the United States to, and President of, the International Carbohydrate Organization. He is President of the US Advisory Committee for International Carbohydrate Symposia Inc., and was general chairman of the XIIIth International Carbohydrate Symposium.

His areas of research interest are industrial utilization of carbohydrates, structure/property relations of polysaccharides, design and synthesis of glycosidase inhibitors, synthesis of *C*-glycosyl compounds, polysaccharides as renewable resources, structures of new plant and microbial polysaccharides, development of new food gums, and synthesis of products with biological activity from carbohydrates.

The Whistler Center for Carbohydrate Research has an outstanding facility for analysis of polymer structures using X-ray fiber diffraction (see Fig. 1). The experimental and computational facilties and personnel of this laboratory were put together by Professor Struther Arnott, who directed it from 1970 until 1987. This laboratory has been responsible for much of the definitive structural analyses of biopolymers using X-ray diffraction. Currently, the biopolymer X-ray fiber diffraction laboratory operates under the direction of two of the permanent, full-time faculty members of the Whistler Center.

Associate Professor Rengaswami Chandrasekaran earned BSc (1958), MSc (1960), and PhD (1966) degrees, all in physics with a graduate program specialization in X-ray crystallography, from the University of Madras, India. From 1968 to 1971, he was a post-doctoral fellow in the Department of Biophysics at the University of Chicago. In 1971, he joined the Department of Biological Sciences at Purdue University as a Research Associate of structural biochemistry. After

Fig. 1. X-Ray fiber diffraction laboratory.

three years, he moved to the Indian Institute of Science (Bangalore) as an Assistant Professor. In 1977, he returned to Purdue as a Research Scientist in the X-ray fiber diffraction laboratory of Professor Arnott. In recent years, he has applied the expertise he gained in the determination of molecular structures of nucleic acids, nucleic acid–drug complexes, and polypeptides and the conformational theory of biopolymers to similar problems in industrially important polysaccharides. His research interests include molecular structures of plant, animal, and bacterial polysaccharides and their relation to physical and biological properties; determination of biopolymer structures using X-ray fiber diffraction techniques; crystal structures of oligosaccharides and oligonucleotides; influence of base sequence on nucleic acid geometry; and protein–nucleic acid, protein–polysaccharide, and nucleic acid–drug interactions.

The focus of his work since the establishment of the Whistler Center has been on enhancing our understanding of the molecular structures of some potentially important gel-forming polysaccharides. His studies of several salt forms of the anionic bacterial polysaccharide gellan have revealed that it forms a parallel, half-staggered double helix (Fig. 2) and that interchain hydrogen bonds involving D-glucuronate carboxylate groups are essential for the stability of the double helix. Furthermore, by locating the potassium ions and water molecules in the crystal structure of the potassium salt form, he has identified all important interactions between the polysaccharide chains, counterions, and water molecules which, for the first time, provide a structural explanation for the marked differences in the gelation behavior of monovalent and divalent cation salts of gellan. Dr Chandrasekaran has also shown that the neutral capsular polysaccharide of *Rhizobium trifolii*, which has a doubly branched repeating unit, can form either a single or double helix in which the side chain interactions are crucial for gelation.

His current research activities in this area of polysaccharide research are centered around (1) determinations of the molecular architectures of the succinoglycans of *Agrobacter* sp., extracellular polysaccharides of *Rhizobium* sp., and those of *Alcaligenes* sp. known as rhamsan and welan, which have the same main chain as gellan, but which are chemically different and do not gel, and (2) studies of polysaccharide–polysaccharide and polysaccharide–protein interactions using computer graphics.

Assistant Professor Rick P. Millane was trained as an electrical engineer, earning his BEng and PhD (1981) degrees in electrical engineering from the University of Canterbury, New Zealand. His PhD research involved information processing for X-ray crystallography,

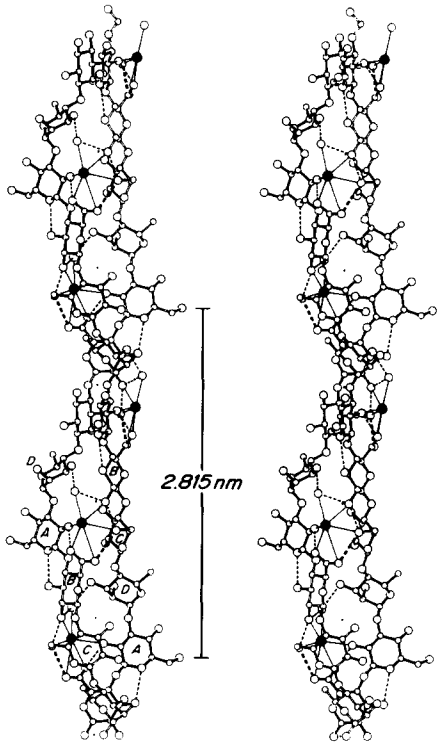

Fig. 2. A stereo view normal to the molecular axis of the gellan double-helix and the coordinating potassium ions (●) and water molecules (○). The hydrogen bonds within the chain (— — —), and between the chains (— — —), are shown along with the six ligands attached to the potassium (——) ion. In this tetrasaccharide repeating unit, *A*, *B*, *C* and *D* are β-D-Glc*p*, β-D-GlcA*p*, β-D-Glc*p*, and α-L-Rha*p*, respectively (Chandrasekaran *et al.*, 1988).

radio engineering, and cardiology. He came to Purdue University as a Post-doctoral Research Associate, also in the laboratory of Professor Arnott, in 1982. Dr Millane's research interests include determination of the molecular structures of polysaccharides and nucleic acids using X-ray fiber diffraction techniques and their relation to physical and biological properties, computer-aided processing of diffraction data from oriented fibers, image processing, diffraction theory for disordered helical particles, Fourier theory, phase retrieval, algorithms for structure determination from fiber diffraction data, polymer conformational analysis, theory and simulation of polymer aggregation and gel formation, computer graphics, and algorithms for supercomputers. He has developed a computerized system for the accurate measurement of X-ray diffraction data from oriented specimens of polymers. This system has extended the range of polymers susceptible to X-ray diffraction analysis by sharpening the discrimination between competing models, as well as making accessible quantitative diffraction data from noncrystalline specimens.

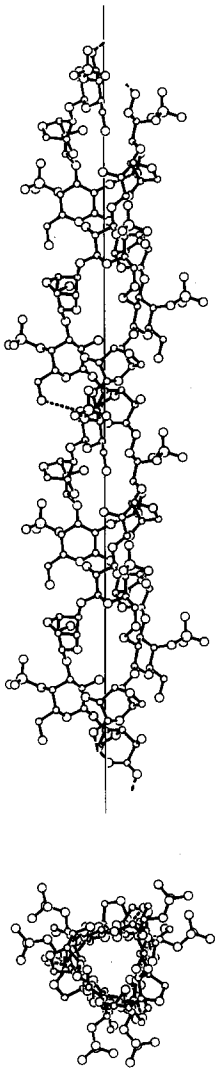

Fig. 3. A side view of the κ-carrageenan double-helix. The two chains are offset from the ideal half-staggered position by 1 Å translation along and 28° rotation about the helix-axis. (———) Interchain hydrogen bonds (Millane *et al.*, 1988).

Dr Millane has made important contributions to the determination of the three-dimensional structures of three gel-forming polysaccharides and six specific sequence nucleic acids and our knowledge of structure–property relations. Using X-ray diffraction techniques, he has now shown that κ-carrageenan forms a novel double helix (Fig. 3), distinctly different from that of ι-carrageenan, which may explain the differences in physical properties between these two polymers.

The goal of the Center is to have eight to ten permanent full-time faculty members. The faculty will be expanded from the current three to

five in the near future. Specific projects already underway in the Center are as follows:

Chemical structure of a potential emulsifying gum
Chemical structure of a new bacterial polysaccharide
Molecular structures of gel-forming polysaccharides
Commodity and food-processing wastes as a source of industrial gums
Removal of color from polysaccharide preparations
Methods of locating acetyl groups in polysaccharides
Preparation of biodegradable plastics
Control of starch chemistry
Preparation of bulking agents
Preparation of carbohydrate-based, high-intensity sweeteners
Preparation and assay of glycosidase inhibitors
Preparation of bio-active carbohydrates
Preparation of pseudopolysaccharides with biological activities

The Whistler Center is associated with the Department of Food Science, which is also new at Purdue, being formed in 1983 within the School of Agriculture. The department has twelve faculty and modern, well-equipped facilities (Fig. 4). Research activities in the department revolve around food chemistry, food biochemistry, toxicology, food microbiology, food processing, and process control.

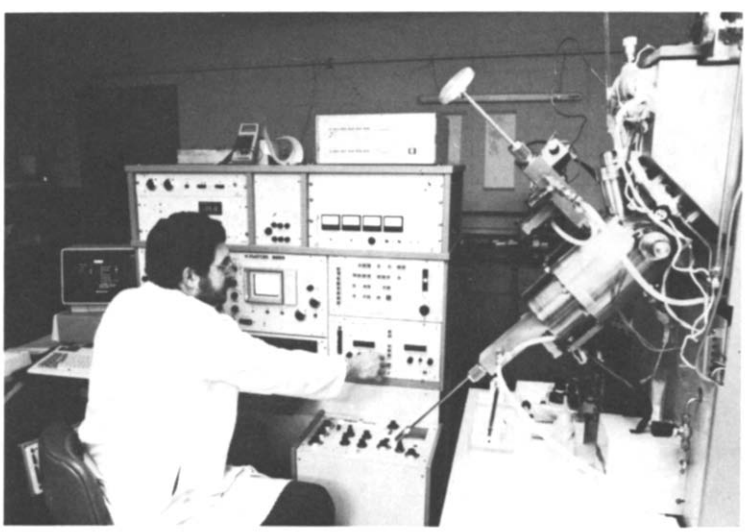

Fig. 4. Mass spectrometer.

Graduate students of the full-time Center faculty may choose to earn MSc or PhD degrees either in food science or in carbohydrate structure and function, with a specialization in either carbohydrate chemistry or polymer X-ray crystallography. Students may also earn degrees in the departmental programs of associated faculty members. Several collaborative research projects between full-time and associated faculty are underway.

Purdue University has solid reputations in science, engineering, and agriculture. It has an enrolment of approximately 48 000 students on four campuses in the State of Indiana (USA); the central campus with its more than 33 000 students is located in West Lafayette. Purdue University has been a leader in research on natural resources and their applications. Its international stature in carbohydrate chemistry is due to the accomplishments of Professor Whistler. Worldwide recognition of achievements enables Purdue to attract distinguished faculty, outstanding students, and broad-based support from government and industry.

Associated Faculty	*Department(s)*	*Research Interests*
Charles E. Bracker, Jr.	Botany and Plant Pathology	Electron microscopy; chitin biosynthesis; secretion of cell wall materials; fine structure of fungal cell walls
Nicholas C. Carpita	Botany and Plant Pathology	Structural analysis of plant cell-wall polysaccharides; biosynthesis of plant polysaccharides; structure of arabinogalactan-proteins
Ching-Jer Chang	Medicinal Chemistry and Pharmacognosy	Molecular microencapsulation; cyclodextrin inclusion complexes; solution and solid state NMR
Li Fu Chen	Food Science	Biomass conversion; immobilized enzymes; fibers from cellodextrins
James R. Daniel	Foods and Nutrition	Synthesis and testing of carbohydrate-based, noncariogenic sweeteners

Peter F. Heinstein	Medicinal Chemistry and Pharmacognosy	Oligosaccharides in transmembrane signaling
Thomas L. Housley	Agronomy	Fructan biosynthesis and turnover
Allen W. Kirleis	Food Science	Milling properties; nutritional quality and food uses of sorghum, wheat and corn
Michael R. Ladisch	Agricultural Engineering, Chemical Engineering	Oligosaccharide separation; cellulose hydrolysis; polysaccharide adsorbents
Philip S. Low	Chemistry	Oligosaccharides in transmembrane signaling; membrane glycoproteins
Jerry L. McLaughlin	Medicinal Chemistry and Pharmacognosy	Structural analysis of saponins and other glycosides; mass spectrometry
Jay S. Marks	Food Science, Agricultural Engineering	Pulse combustion drying
Ramani Narayan	Laboratory of Renewable Resources Engineering	Cellulosic graft copolymers; microbial *exo*-polysaccharides
G. Narsimhan	Agricultural Engineering	Colloidal phenomena in food processing; foam fractionation; stability of foams; rheology of emulsions
Martin R. Okos	Agricultural Engineering	Immobilized-cell reactors; computer-aided design; water transport and drying phenomena
John A. Patterson	Animal Science	Anaerobic microbial hydrolysis of cellulose, hemicelluloses, and starch; microbial production of polysaccharides involved in attachment
Rakesh K. Singh	Food Science, Agricultural Engineering	Thermal (DSC) and rheological properties of biopolymers; carbohydrate-protein interactions

Robert L. VanEtten	Chemistry	Structures of oligosaccharides of glycoproteins via high-resolution NMR; kinetics and mechanism of glycosidic bond hydrolysis via NMR
Jeffrey J. Volenec	Agronomy	Genetic regulation of starch structure and metabolism; sucrose metabolism and plant growth

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