

Advances in Experimental Medicine and Biology

Volume 705

Editorial Board:

IRUN R. COHEN, *The Weizmann Institute of Science*

ABEL LAJTHA, *N. S. Kline Institute for Psychiatric Research*

JOHN D. LAMBRIS, *University of Pennsylvania*

RODOLFO PAOLETTI, *University of Milan*

For other titles published in this series, go to
www.springer.com/series/5584

Albert M. Wu
Editor

The Molecular Immunology of Complex Carbohydrates-3

 Springer

Editor

Albert M. Wu
Glyco-Immunochemistry Research Laboratory
Institute of Molecular and Cellular Biology
College of Medicine
Chang-Gung University
Kwei-Shan, Tao-Yuan 333
Taiwan
amwu@mail.cgu.edu.tw

ISSN 0065-2598

ISBN 978-1-4419-7876-9

e-ISBN 978-1-4419-7877-6

DOI 10.1007/978-1-4419-7877-6

Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2011926797

© Springer Science+Business Media, LLC 2011

All rights reserved. This work may not be translated or copied in whole or in part without the written permission of the publisher (Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA), except for brief excerpts in connection with reviews or scholarly analysis. Use in connection with any form of information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed is forbidden.

The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Winifred M. Watkins

August 1924-October 2003

On 3 October 2003, Winifred Watkins died, and even now, I can remember the sadness I felt when I heard the news. Three weeks before her death, I met her at a meeting in Cambridge organised by the Lister Institute in honour of Walter Morgan, who had died earlier in the year. Despite being wheelchair-bound following an earlier stroke, Winifred was still enjoying talking about science. Winifred was not well enough to give her own tribute to Walter but did correct others who strayed from the facts. During lunch, I had the feeling she was saying goodbye to those of us who had worked with her and Walter. I remember laughing as she persuaded Marcela Contreras to push her wheelchair back to the car by the shortest but, for Marcela, most dangerous route, given the height of Marcela's stilettos! That was the last time I saw Winifred. News of Winifred's death, a few weeks later, did not come as a surprise. In many ways, Walter and Winifred were an inseparable scientific team, and their passing within months of each other brought to the end a golden era of research into carbohydrate blood-group antigen structure.

Winifred Watkins was born in London, on 6 August 1924, the younger daughter of a process engraver who was an accomplished amateur painter. She began her schooling in London and, in 1935, was awarded a scholarship at Godolphin and Latymer School, where she was able to pursue her studies of the sciences. During the war, the school was evacuated to the Berkshire. Newbury was a boys' school that had teaching laboratories in which Winifred gained permission to study sciences alongside her male counterparts. In 1940, she returned to London and graduated in 1942 with her Higher School Certificate. The war precluded her entry to university, and she joined the Biochemistry Department of the Lister Institute in Chelsea Bridge Road, London, as a technician. At the time, the Lister was a "hot bed" of scientific ideas and research, and this stimulated her to study at Chelsea College in the evenings to gain her honours degree in chemistry in 1947. During this time, she worked with Walter Morgan on blood-group substances, and in 1944 they produced enough data for her first publication. This seems to have been a

contentious event as she had no degree and was required to have written permission from the directors of the Lister Institute before the paper was accepted. Having learnt from her own earlier experiences, she encouraged her younger technicians to undertake research projects and publish papers, realising the benefit this can bring; many went on to gain their own Ph.D.s. Indeed, my first-ever publication with Winifred was whilst I was a sandwich student, a year before I gained my own undergraduate degree.

In 1947, she began her post-graduate studies at St. Bartholomew's Hospital Medical School, London, with Arthur Wormall, a renowned immunochemist. She studied the action of nitrogen mustards on the immunological properties of proteins. In 1950, she returned as a post-doctoral fellow to work with Walter Morgan at the Lister Institute, and this was the start of their lifelong scientific partnership.

Between 1957 and 1958, she and Walter uncovered the relationships between the H antigen and the ABO system and, using serological and biochemical techniques, described the structure of the ABH and Lewis blood-group antigens. In the late 1950s, Walter and Winifred speculated on the mechanisms involved in the biosynthesis of the blood-group antigens, and this led to the proposal that the products of the *ABO*, *H*, and *Le* genes were glycosyltransferases that transferred terminal sugars from nucleotide sugar donors onto growing oligosaccharide chains. In 1960, Winifred was awarded a Henry Wellcome Travel Fellowship and spent a sabbatical year in Zev Hassid's laboratory at the University of California, Berkeley, where pioneering work on glycosyltransferases was underway. During that time, she was involved with work leading to the discovery of the enzyme lactose synthetase. In 1966, Winifred proposed, without experimental evidence, that glycosyltransferases were responsible for the production of A, B, H, and Le antigens. The pathways predicted helped explain the variation in H antigen levels in individuals with A, B, AB, and O blood types and predicted that individuals from Bombay would lack the α -2-fucosyltransferase product of the *H* gene. The scheme also explained why secretors of H substance who possessed the *Le* gene would always produce Leb^b, whereas non-secretors would produce Lea^a. Over the next 5 years in Winifred's laboratory and in Vic Ginsburg's laboratory in the USA, the appropriate enzymes were found to prove the hypothesis, and by the early 1970s, glycosyltransferase assays were carried out routinely within laboratories. This allowed analyses of rare blood groups and chimeras, tissue distribution studies, and the onco-developmental nature of the antigens. This period was the heyday of the Lister Institute, which was also home to Rob Race, Ruth Sanger, Pat Tippet, and Marcela Contreras—with whom Winifred had many lively discussions and for whom she had an enduring respect.

In 1975, the Lister Institute closed, and after much discussion, Winifred moved with her group to the MRC Clinical Research Centre in Harrow, where she was the only non-medically qualified departmental head, to lead the new Division of Immunochemical Genetics. Their work on glycosyltransferases continued, focusing on localisation, characterisation, purification, and, finally, gene cloning. The underlying causes of blood group ABO, H, and Le anomalies and weak subgroups

were unravelled. Support for the allelic basis of the *A* and *B* genes was found when the group demonstrated the overlapping specificity of the *A* and *B* transferases. Work on fucosyltransferases supported the idea put forward by Rafael Oriol that *H* and *Se* genes were responsible for the production of H antigen on red cells and in secretions, respectively, and demonstrated relationships between some but not all fucosyltransferases. Further research demonstrated specificities of a range of fucosyltransferases and highlighted their roles in leukaemias. Following the production of polyclonal and monoclonal antibodies against the purified *A* transferase and the fucosyltransferases, the work moved into molecular biology, using polyclonal antibodies to screen expression libraries.

In 1984, Winifred's 60th birthday was celebrated with a Biochemical Society meeting in London, which many of her colleagues and friends attended. However, following a very positive quinquennial review, the decision was made to close the Division of Immunochemical Genetics when Winifred retired from the MRC in 1989. The work was curtailed, and the group disbanded. The closure of the Division at the MRC was a bitter blow, particularly as it followed such an excellent review of the research. I am sure she deeply regretted that the work into blood-group antigen biosynthesis did not continue in the UK. Winifred then moved to the Hammersmith Hospital, where she was able to follow up work on fucosyltransferase and sialyltransferase expression in normal white cell maturation and leukaemia. This work continued until the millennium, when Winifred stopped laboratory based research and concentrated on more academic work, until a stroke prevented her from continuing.

During her lifetime, the impact she made in glycobiology and transfusion science can be demonstrated by the awards she received: In 1965, she was awarded the Oliver Memorial Fund award for her work in transfusion science; in 1967, she received the Karl Landsteiner Award of the American Association of Blood Banks; and in 1969, the Paul Ehrlich-Ludwig Darmstadter Medal and Prize. In the same year, she was elected to the Fellowship of the Royal Society of London, and in 1970, she was awarded the William Julius Mickle Fellowship at the University of London. She was presented with the Kenneth Goldsmith Award of the British Blood Transfusion Society in 1986, the Royal Medal of the Royal Society in 1988, the Franz Oehlecker Medal of the German Society of Transfusion Medicine and Immunohaematology in 1989, and the Phillip Levine Award of the American Society of Chemical Pathologists in 1990. She also received an Honorary DSc in chemistry from the University of Utrecht in 1990. She was elected as a member or a fellow to the Royal Society of London (Fellow, 1969), The Royal College of Pathologists (Fellow, 1983), the International Society of Blood Transfusion (Honorary Member, 1984), the Polish Academy of Sciences (Foreign Member, 1988), The Royal College of Physicians (Fellow, 1990), the Japanese Biochemical Society (Honorary Member, 1990), the British Blood Transfusion Society (Honorary Member, 1996), The Royal Swedish Academy of Sciences (Member, 1988), the Academy of Medical Sciences (Fellow, 1998), and the Biochemical Society (Honorary Member, 2000).

On a personal level, Winifred expected absolute commitment to work, and she was both supportive and protective of her staff. I well remember how, when I was a very young doctoral student on my first trip to Canada, she paid for my lunch at the Hilton for the whole meeting to make sure that I wasn't short of money and made sure to keep a "motherly eye" on me. Twenty years later, when her laboratory was closing, she called me over and gave me equipment and materials "knowing I would make good use of them". Winifred had a love of both good food and wine. When she died, I helped clear her flat and found a collection of labels from wine bottles neatly inscribed with the occasion and date with a comment about both the quality of the wine (and the food) and the occasion. These included labels from the meeting when she heard the Lister Institute was closing ("unbelievable" and "frustrating") to one celebrating her 60th birthday ("memorable").

Winifred will always be remembered as a pioneer in glycobiology and blood-group antigen research, one of the most respected scientists in the UK, and one of the most talented women scientists. During her working life, Winifred gave many memorable lectures and was highly respected in her field. With her enthusiasm for her work, she had the ability to make glycobiology fascinating to those with little interest in biochemistry. Winifred was an extraordinary scientist in many respects, succeeding in what was, at a time, essentially a male-dominated area. She was intelligent, determined, and self-motivated. She enjoyed interacting with other scientists, and she had particularly strong ties with Poland through her friendships with Jerzy Koscielak and a number of Polish students who came on sabbatical to the laboratory. She also had friendly links with Albert M. Wu. She participated in two meetings organised by him: Molecular Immunology of Complex Carbohydrates (MICC)-1 (College Station, TX, 1985) and MICC-2 (Taipei, Taiwan, 1999). Winifred contributed with excellent meeting lectures and articles at MICC-2, and moreover, Winifred and Albert published several papers together. Winifred also had strong links with scientists in Sweden, USA, Israel, Japan, and France. Until her first stroke, Winifred continued to attend meetings, thoroughly enjoying simply being part of the science scene and engaging in discussions and debate.

Although it is difficult to separate "Watkins and Morgan", Winifred was, in her own right, a brilliant researcher. When Walter was in his late 80s and worked at the CRC characterising the Sda antigen and elucidating its relationship with the Tamm-Horsfall protein, Winifred was always mindful of his needs. Walter saw Winifred as his protégé and as a highly talented scientist in her own right. He was always anxious that she be recognised as an independent researcher and valued both their academic and personal relationships. For those of us who worked with Winifred, she could be a hard taskmaster; visits to the library, for example, were done on our own time, and holidays were fitted around work, not vice versa. Lectures were practised endlessly, and mistakes were not allowed; preparation was key to the accomplished speaker. Papers were written and re-written until they were perfect, and doctoral theses did not contain a single mistake. On the other hand, she was inspirational, easy to talk to, and happy to share her knowledge and experience. There are still occasions when I realise what a font of knowledge she had. I learnt

much from Winifred, and in many ways, I wish she had lived to see the upsurge in glycobiology research that has taken place over the past 5 years. Those of us who worked with her, knew her professionally, and shared her friendship will always be grateful for the experience.

Pamela Greenwell
School of Biosciences
University of Westminster
115 New Cavendish Street
London, UK



Four glyco-immune chemists met at the XIII International Symposium on Glycoconjugates in Seattle, WA, on 23 August 1995. From *left*: W.T.J. Morgan, W.M. Watkins, J. Koscielak, and R.W. Jeanloz



Left: Dr. W.M. Watkins commented on her talk at the MICC-1, 14 September 1985: “No one was assigned to give a historical perspective of the past except me”
Right: Two cyst glycoprotein pioneers, Drs. E. Kabat (*left*) and W.M. Watkins (*right*), met at a party honoring Dr. Kabat in Seattle, WA, on 31 August 1995



Left: Dr. W.M. Watkins as a chair at the MICC-2, 29 August 1999
Right: Dr. W.M. Watkins (*left*) and Dr. A.M. Wu (*right*) in front of Wu's poster at the XV International Carbohydrate Symposium, Yokohama, Japan, 14 August 1990



European and Taiwanese glyco-immunologists met at the MICC-2 symposium on 31 August 1999. From *left*: Drs. E. Lisowska, M. Lin (Mackay Memorial Hospital), W.M. Watkins, and M. Duk



Dr. P.W. Cheng (*far left*) was teaching Dr. W.M. Watkins (*second from left*) to use chopsticks at the MICC-2 symposium dinner on 29 August 1999. Also pictured: Dr. N. Sharon (*second from right*) and Mrs. N. Sharon (*far right*)



Dr. W.M. Watkins (*left*) with microbial lectin experts, Drs. N. Gilboa-Garber (*middle*) and N.C. Garber (*right*), from Bar-Ilan University, Israel, at the MICC-2 symposium on 30 August 1999



Participants of the Third International Symposium on Molecular Immunology of Complex Carbohydrates (MICC-3)

國際 醣類 分子免疫學 學術會議-3

Institute of Biological Chemistry, Academia Sinica, Taipei, Taiwan, 8-12 July 2007

Preface

This is the third time I have organized the international symposium on Molecular Immunology of Complex Carbohydrates (MICC), which was held at the Institute of Biological Chemistry (IBC), Academia Sinica, Taipei, Taiwan, 8–12 July 2007, as a satellite meeting of the 19th International Glycoconjugate Organization (IGO) meeting held 15–20 July 2007 in Cairns, Australia. MICC-2 was held at the same place from 28 August to 2 September 1999, after the 15th IGO meeting in Tokyo, Japan. We have arranged two other glyco symposia and three workshops since MICC-2. MICC-2 (*Adv Exp Med Biol* [2001]; 491) was selected as “an excellent textbook” from Kluwer Academic Publishers in 2002. In this MICC-3 book, three quarters of the content are based on lectures and posters of the MICC-3 symposium, and one quarter is from workshops and promotional materials. The book is divided into an Introduction, eight sections, and an appendix.

The Introduction (Part I), “Glyco Experiences”, shares in one essay the serendipity of scientific discoveries in the glycosciences obtained from the lifetime experiences of Dr. Y.C. Lee (Department of Biology, Johns Hopkins University, MD, USA). In the second essay, Noriko Takahashi (Graduate School of Pharmaceutical Sciences, Nagoya City University, Nagoya, Japan) describes 30 years of work devoted to determining the structures of *N*-glycans.

The main text starts with Part II, “Blood Group ABH/Le-related Antigens,” to pay a tribute to the work of three pioneers in this field: Walter T.J. Morgan, Elvin A. Kabat, and – especially – Winifred M. Watkins, to whom this book is dedicated. This section presents the advanced concepts concerning the structure and functions of these antigens. In my comprehensive review on human blood group ABH/i, Le^{a,b,x,y}, and sialyl Le^{a,x} glycotopes of human ovarian cyst glycoproteins, I begin with the history of the most important findings and continue to our contemporary view.

The interactions of plant, bacterial, and animal lectins with carbohydrates (and proteins) are thoroughly presented in eight contributions to Part III. Recognition intensities of mammalian structural units, ligand clusters, and polyvalency in the lectin–glycan interaction are some of the important issues covered in this section. The review on the ligand selectivity of adhesion/growth-regulatory galectins is a report of our decade-long collaboration with two glyco labs in Munich, Germany. The evidence for various regulatory roles of glycolipids is continuously increasing. Six contributions in Part IV describe the structures and functions of gangliosides

and microbial glycolipids. The physiological roles of other glycoconjugates (glycoproteins, glycans, cellular receptors) in humans, animals, sponges, and bacteria, as well as aging-related alterations of the glycosylation profile in humans, are the subject of eight articles in Part V. The role of carbohydrates as antigens and regulators of the immune response is widely studied in the four reviews included in Part VI. Malignant transformation of cells is associated with profound changes of glycosylation, and some cancer-related glycoforms play a role in cancer development and metastasis. These aspects of the glycobiology of cancer are presented in five articles in Part VII. New methodologies in glycosynthesis and lectin–carbohydrate binding assays, and strategies for treatment as crucial applications, are described in four articles in Part VIII. Three of them present results obtained by Taiwanese research groups.

An appendix is added at the end of the proceedings to correct typographical and structural errors found in MICC-1 (*Adv Exp Med Biol* [1988]; 228) and MICC-2 (*Adv Exp Med Biol* [2001]; 491).

After the MICC-2 symposium, we lost three blood-group pioneers: Drs. Walter T.J. Morgan (October 1900–February 2003), Elvin A. Kabat (September 1914–June 2000), and Winifred M. Watkins (August 1924–October 2003). Drs. Kabat and Watkins have contributed timeless works to the MICC series. Dr. Kabat's obituary was included in the MICC-2 issue, and Dr. Watkins's obituary is included in this issue.

To this day, this series continues to provide valuable knowledge in the field of glycotopes, structures and functions of complex carbohydrates, recognition factors of lectins, biomolecular interactions, and other glycosciences. I hope these proceedings reflect our worldwide connections, including the friendly collaboration of our lab with colleagues in Taiwan, and other parts of the world, especially Poland, Germany, Israel, Belgium, USA, Japan, Italy, England, India, and China.

As a symposium chair, I owe special thanks to our three co-chairs: Drs. S.H. Wu, C.H. Lin, and K.H. Khoo from IBC, who were the actual driving forces for this symposium and to Drs. Y.C. Lee, R. Schauer, and A. Kobata for their important comments and suggestions. I also thank many members of our lab and staff of IBC, as they worked from early morning to late evening for several months. I also wish to thank the director of IBC, Dr. M.T. Tsai, and the president, C.H. Wong, who provided excellent facilities; the National Science Council (NSC), the Ministry of Education, the Foundation for Research and Education of Glycoscience, and the Research Promotion Center for Life Science of NSC for their financial support; and Chang Gung University for Workshops. I also appreciate the help of Amvo Publishing Company in Taiwan, and Drs. E. Lisowska, H.J. Gabius, Z. Yang, and Ms. Y.P. Gong for their assistance in editing this book. Without their efforts, the symposiums, workshops, and publication of these proceedings would be impossible. Thanks again to all contributors and participants.

Tao-yuan, Taiwan
10 September 2011

Albert M. Wu

Contents

Part I Introduction to Glyco-Experiences

- 1 Serendipity in Scientific Discoveries: Some Examples in Glycosciences.....** 3
Yuan-Chuan Lee
- 2 My 30-Year Devotion to the *N*-Linked Oligosaccharide Structures** 15
Noriko Takahashi

Part II Blood Group ABH/Le-Related Antigens

- 3 Human Blood Group ABH/Ii, Le^{a,b,x,y}, and Sialyl Le^{a,x} Glycotopes; Internal Structures; and Immunochemical Roles of Human Ovarian Cyst Glycoproteins** 33
Albert M. Wu
- 4 Lewis Glyco-Epitopes: Structure, Biosynthesis, and Functions** 53
Hui-Li Chen
- 5 A Unique Endo- β -Galactosidase that Cleaves Both Blood Group A and B Glycotopes** 81
Su-Chen Li, Kimberly M. Anderson, and Yu-Teh Li

Part III Lectins

- 6 Recognition Roles of Mammalian Structural Units and Polyvalency in Lectin–Glycan Interactions.....** 99
Albert M. Wu, Jia-Haw Liu, Tanuja Singh, and Zhangung Yang

7 Adhesion/Growth-Regulatory Galectins: Insights into Their Ligand Selectivity Using Natural Glycoproteins and Glycotopes	117
Albert M. Wu, Tanuja Singh, Jia-Hau Liu, Sabine André, Martin Lensch, Hans-Christian Siebert, Mickael Krzeminski, Alexandre M.J.J. Bonvin, Herbert Kaltner, June H. Wu, and Hans-Joachim Gabius	
8 Glycotope Structures and Intramolecular Affinity Factors of Plant Lectins for Tn/T Antigens	143
Pierre Rougé, Willy J. Peumans, Els J.M. Van Damme, Annick Barre, Tanuja Singh, June H. Wu, and Albert M. Wu	
9 The Five Bacterial Lectins (PA-IL, PA-IIL, RSL, RS-IIL, and CV-IIL): Interactions with Diverse Animal Cells and Glycoproteins	155
Nechama Gilboa-Garber, Keren D. Zinger-Yosovich, Dvora Sudakevitz, Batya Lerrer, Anne Imberty, Michaela Wimmerova, Albert M. Wu, and Nachman C. Garber	
10 On the Differential Sialic Acid Specificity of Lectins from Different Parts of <i>Saraca indica</i>	213
Bishnu P. Chatterjee and Mainak Majumder	
11 Regulation of Lectin Production by the Human Pathogens <i>Pseudomonas aeruginosa</i> and <i>Chromobacterium violaceum</i>: Effects of Choline, Trehalose, and Ethanol	229
Nachman C. Garber, Keren D. Zinger-Yosovich, Dvora Sudakevitz, Itshak Axelrad, and Nechama Gilboa-Garber	
12 Non-carbohydrate-Mediated Interaction of Lectins with Plant Proteins	257
Jared Q. Gerlach, Michelle Kilcoyne, Seron Eaton, Veer Bhavanandan, and Lokesh Joshi	
13 Novel Concepts About the Role of Lectins in the Plant Cell	271
Els J.M. Van Damme, Elke Fouquaert, Nausicaä Lannoo, Gianni Vandenborre, Dieter Schouppe, and Willy J. Peumans	
Part IV Structures and Functions of Glycolipids	
14 Role of Gangliosides and Plasma Membrane-Associated Sialidase in the Process of Cell Membrane Organization	297
Sandro Sonnino, Vanna Chigorno, Massimo Aureli, Anie Priscilla Masilamani, Manuela Valsecchi, Nicoletta Loberto, Simona Prioni, Laura Mauri, and Alessandro Prinetti	

15	9-<i>O</i>-Acetyl GD3 in Lymphoid and Erythroid Cells	317
	Kankana Mukherjee, Suchandra Chowdhury, Susmita Mondal, Chandan Mandal, Sarmila Chandra, and Chitra Mandal	
16	GM3 Upregulation of Matrix Metalloproteinase-9 Possibly Through PI3K, AKT, RICTOR, RHOGDI-2, and TNF-α Pathways in Mouse Melanoma B16 Cells	335
	Pu Wang, Xiaodong Wang, Peixing Wu, Jinghai Zhang, Toshinori Sato, Sadako Yamagata, and Tatsuya Yamagata	
17	Pathological Roles of Ganglioside Mimicry in Guillain–Barré Syndrome and Related Neuropathies	349
	Robert K. Yu, Toshio Ariga, Seigo Usuki, and Ken-ichi Kaida	
18	Structure and Function of Glycolipids in Thermophilic Bacteria	367
	Feng-Ling Yang, Yu-Liang Yang, and Shih-Hsiung Wu	
19	Lipooligosaccharides of <i>Neisseria</i> Species: Similarity Between <i>N. polysaccharea</i> and <i>N. meningitidis</i> LOSs	381
	Chao-Ming Tsai	

Part V Structures and Functions of Complex Carbohydrates

20	Roles for <i>N</i>- and <i>O</i>-Glycans in Early Mouse Development	397
	Suzannah A. Williams and Pamela Stanley	
21	Glycobiology in the Field of Gerontology (Glycogerontology)	411
	Akira Kobata	
22	Galectins in Regulation of Apoptosis	431
	Fu-Tong Liu, Ri-Yao Yang, Jun Saegusa, Huan-Yuan Chen, and Daniel K. Hsu	
23	Avian and Human Influenza Virus Receptors and Their Distribution	443
	Yasuo Suzuki	
24	Importance of a Factor VIIIc-Like Glycoprotein Expressed in Capillary Endothelial Cells (eFactor VIIIc) in Angiogenesis	453
	Dipak K. Banerjee, Caroline M. Oliveira, José J. Tavárez, Viswa N. Katiyar, Subiman Saha, Juan A. Martínez, Aditi Banerjee, Aurymar Sánchez, and Krishna Baksi	

25	Mucin <i>O</i>-Glycan Branching Enzymes: Structure, Function, and Gene Regulation	465
	Pi-Wan Cheng and Prakash Radhakrishnan	
26	Studying Carbohydrate Self-Recognition in Marine Sponges Using Synthetic Aggregation Factor Epitopes.....	493
	Johannis P. Kamerling and Adriana Carvalho de Souza	
27	Docking of Chitin Oligomers and Nod Factors on Lectin Domains of the LysM-RLK Receptors in the <i>Medicago-Rhizobium</i> Symbiosis	511
	Pierre Rougé, Wim Nerinckx, Clare Gough, Jean-Jacques Bono, and Annick Barre	

Part VI Glycoimmunology

28	<i>O</i>-Acetylated Sialic Acids and Their Role in Immune Defense	525
	Roland Schauer, G. Vinayaga Srinivasan, Dirk Wipfler, Bernhard Kniep, and Reinhard Schwartz-Albiez	
29	Sialylated and Sulfated Carbohydrate Ligands for Selectins and Siglecs: Involvement in Traffic and Homing of Human Memory T and B Lymphocytes	549
	Reiji Kannagi, Katsuyuki Ohmori, Guo-Yun Chen, Keiko Miyazaki, Mineko Izawa, and Keiichi Sakuma	
30	Diversity of Natural Anti-α-Galactosyl Antibodies in Human Serum	571
	Elwira Lisowska and Maria Duk	
31	Significance of Serum Glycoprotein Profiles in Spontaneous Tolerance After Liver Allograft Transplantation	585
	Pei-Weng Wang and Tai-Long Pan	

Part VII Glycobiology of Cancer

32	Hematogenous Metastasis: Roles of CD44v and Alternative Sialofucosylated Selectin Ligands	601
	Konstantinos Konstantopoulos and Susan N. Thomas	
33	Regulation of Glycosyltransferase Genes in Apoptotic Breast Cancer Cells Induced by L-PPMP and Cisplatin.....	621
	Rui Ma, Elizabeth A. Hopp, N. Matthew Decker, Audrey Loucks, James R. Johnson, Joseph Moskal, Manju Basu, Sipra Banerjee, and Subhash Basu	

34	Aberrant Glycosphingolipid Expression and Membrane Organization in Tumor Cells: Consequences on Tumor–Host Interactions	643
	Alessandro Prinetti, Simona Prioni, Nicoletta Loberto, Massimo Aureli, Valentina Nocco, Giuditta Illuzzi, Laura Mauri, Manuela Valsecchi, Vanna Chigorno, and Sandro Sonnino	
35	Human KDN (Deaminated Neuraminic Acid) and Its Elevated Expression in Cancer Cells: Mechanism and Significance	669
	Sadako Inoue, Ken Kitajima, Chihiro Sato, and Shinji Go	
36	Polysialic Acid Bioengineering of Cancer and Neuronal Cells by <i>N</i>-Acyl Sialic Acid Precursor Treatment.....	679
	Robert A. Pon, Wei Zou, and Harold J. Jennings	
 Part VIII Glyco Applications		
37	Synthesis of Hemagglutinin-Binding Trisaccharides.....	691
	Cheng-Chung Wang, Suvarn S. Kulkarni, Medel Manuel L. Zulueta, and Shang-Cheng Hung	
38	Fabrication and Applications of Glyconanomaterials	727
	Po-Chiao Lin, Avijit Kumar Adak, and Chun-Cheng Lin	
39	Glycan Arrays to Decipher the Specificity of Plant Lectins.....	757
	Els J.M. Van Damme, David F. Smith, Richard Cummings, and Willy J. Peumans	
40	Targeting C-Type Lectin for the Treatment of Flavivirus Infections	769
	Szu-Ting Chen, Yi-Ling Lin, Ming-Ting Huang, Ming-Fang Wu, and Shie-Liang Hsieh	
	Appendix	777
	Index.....	787

Contributors

Avijit Kumar Adak

Department of Chemistry, National Tsing Hua University, Hsinchu, Taiwan

Kimberly M. Anderson

Department of Biochemistry, Tulane University Health Sciences Center,
School of Medicine, New Orleans, LA 70112, USA

Sabine André

Faculty of Veterinary Medicine, Institute of Physiological Chemistry,
Ludwig-Maximilians-University Munich, Veterinärstr. 13, 80539 Munich,
Germany

Toshio Ariga

Institute of Molecular Medicine and Genetics, Medical College of Georgia,
Augusta, GA 30912, USA;
Institute of Neuroscience, Medical College of Georgia, Augusta, GA 30912, USA

Massimo Aureli

Department of Medical Chemistry, Biochemistry and Biotechnology,
Center of Excellence on Neurodegenerative Diseases, University of Milan,
Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Itschak Axelrad

The Mina & Everard Goodman Faculty of Life Sciences, Bar-Ilan University,
Ramat-Gan 52900, Israel

Krishna Baksi

Department of Anatomy and Cell Biology, School of Medicine,
Universidad Central del Caribe, Bayamón 00960-6032, Puerto Rico

Aditi Banerjee

Department of Biochemistry, School of Medicine, University of Puerto Rico,
Medical Sciences Campus, San Juan 00936-5067, Puerto Rico

Dipak K. Banerjee

Department of Biochemistry, School of Medicine, University of Puerto Rico,
Medical Sciences Campus, San Juan 00936-5067, Puerto Rico

Sipra Banerjee

Department of Cancer Biology, Cleveland Clinic Foundation, Cleveland,
OH 44129, USA

Annick Barre

Surfaces Cellulaires et Signalisation chez les Végétaux, UMR UPS-CNRS 5546,
Pôle de Biotechnologie Végétale, 24 Chemin de Borde Rouge,
31326 Castanet Tolosan, France

Manju Basu

Department of Chemistry and Biochemistry, The University of Notre Dame,
Notre Dame, IN 46556, USA

Subhash Basu

Department of Chemistry and Biochemistry, The University of Notre Dame,
Notre Dame, IN 46556, USA

Veer Bhavanandan

Department of Bioengineering, Center for Glycosciences and Technology,
The Biodesign Institute, Arizona State University, Tempe, AZ 85287, USA

Jean-Jacques Bono

Surfaces Cellulaires et Signalisation chez les Végétaux, UMR UPS-CNRS 5546,
24 Chemin de Borde Rouge, 31326 Castanet Tolosan, France

Alexandre M. J. J. Bonvin

Department of NMR Spectroscopy, Bijvoet Center for Biomolecular Research,
Utrecht University, Padualaan 8, 3584 CH Utrecht, The Netherlands

Sarmila Chandra

Kothari Medical Centre, 8/3, Alipore Road, Kolkata, 700027, India

Bishnu P. Chatterjee

West Bengal University of Technology, Salt Lake, 700064, Kolkata, India

Guo-Yun Chen

Department of Molecular Pathology, Aichi Cancer Center, Nagoya
464-8681, Japan

Huan-Yuan Chen

Department of Dermatology, University of California, 3301 C Street, Suite 1400,
Sacramento, CA 95816, USA

Hui-Li Chen

Key Laboratory of Glycoconjugate Research, Ministry of Health,
Department of Biochemistry, Shanghai Medical College, Fudan University,
Shanghai 200032, China

Szu-Ting Chen

Department of Microbiology and Immunology, Institute of Microbiology
and Immunology, National Yang-Ming University, Taipei, Taiwan

Pi-Wan Cheng

Department of Biochemistry and Molecular Biology, College of Medicine and Eppley Institute for Research in Cancer and Allied Diseases, University of Nebraska Medical Center, Omaha, NE 68198-5870, USA

Vanna Chigorno

Department of Medical Chemistry, Biochemistry and Biotechnology, Center of Excellence on Neurodegenerative Diseases, University of Milan, Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Suchandra Chowdhury

Infectious Disease and Immunology Division, Indian Institute of Chemical Biology, 4, Raja S. C. Mullick Road, Kolkata 700032, India

Richard Cummings

Department of Biochemistry, Emory University School of Medicine, Atlanta, GA 30322, USA

Adriana Carvalho de Souza

Department of Bio-Organic Chemistry, Bijvoet Center, Utrecht University, Padualaan 8, CH Utrecht NL-3584, The Netherlands

N. Matthew Decker

Department of Chemistry and Biochemistry, The University of Notre Dame, Notre Dame, IN 46556, USA

Maria Duk

Department of Immunochemistry, Ludwik Hirsfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, 53-114 Wrocław, Poland

Seron Eaton

Department of Molecular and Cellular Biology, Center for Biosensors and Bioelectronics, The Biodesign Institute, Arizona State University, Tempe, AZ 85287, USA

Elke Fouquaert

Department of Molecular Biotechnology, Laboratory of Biochemistry and Glycobiology, Ghent University, Coupure Links 653, 9000 Gent, Belgium

Hans-Joachim Gabius

Faculty of Veterinary Medicine, Institute of Physiological Chemistry, Ludwig-Maximilians-University Munich, Veterinärstr. 13, 80539 Munich, Germany

Nachman C. Garber

The Mina & Everard Goodman Faculty of Life Sciences, Bar-Ilan University, Ramat-Gan 52900, Israel

Jared Q. Gerlach

Glycoscience Group, National Centre for Biomedical Engineering Science, National University of Ireland, Galway, Ireland

Nechama Gilboa-Garber

The Mina & Everard Goodman Faculty of Life Sciences, Bar-Ilan University,
Ramat-Gan 52900, Israel

Shinji Go

Institute of Molecular Biomembranes and Glycobiology, Tohoku Pharmaceutical
University, Sendai, Japan 981-8558

Clare Gough

Laboratoire des Interactions Plantes-Microorganismes, UMR CNRS-INRA,
2594/441, 24 Chemin de Borde Rouge, 31326 Castanet Tolosan, France

Pamela Greenwell (Obituary)

School of Biosciences, University of Westminster, 115 New Cavendish Street,
London, UK

Elizabeth A. Hopp

Department of Chemistry and Biochemistry, The University of Notre Dame,
Notre Dame, IN 46556, USA

Shie-Liang Hsieh

Department and Institute of Microbiology and Immunology,
National Yang-Ming University, Taipei, Taiwan

Daniel K. Hsu

Department of Dermatology, University of California, 3301 C Street, Suite 1400,
Sacramento, CA 95816, USA

Ming-Ting Huang

Department of Microbiology and Immunology, Institute of Microbiology
and Immunology, National Yang-Ming University, Taipei, Taiwan

Shang-Cheng Hung

Genomics Research Center, Academia Sinica, 128, Section 2, Academia Road,
Taipei 115, Taiwan

Giuditta Illuzzi

Department of Medical Chemistry, Biochemistry and Biotechnology,
Center of Excellence on Neurodegenerative Diseases, University of Milan,
Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Anne Imberty

CERMAV-CNRS (Joseph Fourier University), BP 53, 38041 Grenoble,
Cedex 09, France

Sadako Inoue

Bioscience and Biotechnology Center, Nagoya University, Nagoya 464-8601, Japan

Mineko Izawa

Department of Molecular Pathology, Aichi Cancer Center, Nagoya 464-8681, Japan

Harold J. Jennings

Institute for Biological Sciences, National Research Council of Canada,
Ottawa, ON K1A 0R6, Canada

James R. Johnson

Department of Chemistry and Biochemistry, The University of Notre Dame,
Notre Dame, IN 46556, USA

Lokesh Joshi

National Centre for Biomedical Engineering Science, National University
of Ireland, Galway, Ireland;
Department of Bioengineering, The Biodesign Institute, Arizona State University,
Tempe, AZ 85287, USA

Ken-ichi Kaida

Institute of Molecular Medicine and Genetics, Medical College of Georgia,
Augusta, GA 30912, USA;
Institute of Neuroscience, Medical College of Georgia, Augusta, GA 30912, USA

Herbert Kaltner

Faculty of Veterinary Medicine, Institute of Physiological Chemistry,
Ludwig-Maximilians-University Munich, Veterinärstr. 13, 80539 Munich,
Germany

Johannis P. Kamerling

Department of Bio-Organic Chemistry, Bijvoet Center, Utrecht University,
Padualaan 8, 3584 CH Utrecht, The Netherlands

Reiji Kannagi

Research Complex for the Medical Frontiers, Aichi Medical University,
Aichi 480-1195, Japan

Viswa N. Katiyar

Department of Chemistry, InterAmerican University, Metro Campus, San Juan
00919-1293, Puerto Rico

Nava Katri

The Mina & Everard Goodman Faculty of Life Sciences, Bar-Ilan University,
Ramat-Gan 52900, Israel

Michelle Kilcoyne

National Centre for Biomedical Engineering Science,
National University of Ireland, Galway, Ireland;
Department of Bioengineering, Center for Glycosciences and Technology,
The Biodesign Institute, Arizona State University, Tempe, AZ 85287, USA

Ken Kitajima

Bioscience and Biotechnology Center, Nagoya University, Nagoya, Japan 464-8601

Bernhard Kniep

Institut für Immunologie, Medizinische Fakultät “Carl Gustav Carus”,
Technische Universität Dresden, Fetscherstr. 74, D-01307 Dresden, Germany

Akira Kobata

The Noguchi Institute, 1-8-1 Kaga, Itabashi-ku, Tokyo 173-0003, Japan

Konstantinos Konstantopoulos

Department of Chemical and Biomolecular Engineering, The Johns Hopkins
University, Baltimore, MD 21218, USA

Mickael Krzeminski

Department of NMR Spectroscopy, Bijvoet Center for Biomolecular Research,
Utrecht University, Padualaan 8, 3584 CH Utrecht, The Netherlands

Suvarn S. Kulkarni

Genomics Research Center, Academia Sinica, Taipei 115, Taiwan

Nausicaä Lannoo

Department of Molecular Biotechnology, Laboratory of Biochemistry
and Glycobiology, Ghent University, Coupure Links 653, 9000 Gent, Belgium

Yuan-Chuan Lee

Biology Department, Johns Hopkins University, 3400 N. Charles St,
Baltimore, MD 21218, USA

Martin Lensch

Faculty of Veterinary Medicine, Institute of Physiological Chemistry,
Ludwig-Maximilians-University Munich, Veterinärstr. 13, 80539 Munich,
Germany

Batya Lerrer

The Mina & Everard Goodman Faculty of Life Sciences, Bar-Ilan University,
Ramat-Gan 52900, Israel

Su-Chen Li

Department of Biochemistry, Tulane University Health Sciences Center,
School of Medicine, New Orleans, LA 70112, USA

Yu-Teh Li

Department of Biochemistry, Tulane University Health Sciences Center,
School of Medicine, New Orleans, LA 70112, USA

Chun-Cheng Lin

Department of Chemistry, National Tsing Hua University, Hsinchu, Taiwan;
Chemical Biology and Molecular Biophysics, Taiwan International Graduate
Program, Academia Sinica, Taipei, Taiwan

Po-Chiao Lin

Department of Chemistry, National Tsing Hua University, Hsinchu, Taiwan;
Chemical Biology and Molecular Biophysics, Taiwan International Graduate
Program, Academia Sinica, Taipei, Taiwan

Yi-Ling Lin

Institute of Biomedical Sciences, Academia Sinica, Taipei, Taiwan;
Genomics Research Center, Academia Sinica, Taipei, Taiwan

Elwira Lisowska

Department of Immunochemistry, Ludwik Hirszfeld Institute
of Immunology and Experimental Therapy, Polish Academy of Sciences,
53-114 Wrocław, Poland

Jia-Hau Liu

Glyco-Immunochemistry Research Laboratory, Institute of Molecular
and Cellular Biology, College of Medicine, Chang-Gung University,
Kwei-San, Tao-Yuan, 333, Taiwan

Jia-Haw Liu

Glyco-Immunochemistry Research Laboratory, Institute of Molecular and Cellular
Biology, College of Medicine, Chang-Gung University, Kwei-San, Tao-Yuan 333,
Taiwan

Fu-Tong Liu

Department of Dermatology, University of California, 3301 C Street,
Suite 1400, Sacramento, CA 95816, USA

Nicoletta Loberto

Department of Medical Chemistry, Biochemistry and Biotechnology,
Center of Excellence on Neurodegenerative Diseases, University of Milan,
Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Audrey Loucks

Department of Chemistry and Biochemistry, The University of Notre Dame,
Notre Dame, IN 46556, USA

Mainak Majumder

Lab India Ltd., Gurgaon, India

Rui Ma

Department of Chemistry and Biochemistry, The University of Notre Dame,
Notre Dame, IN 46556, USA

Chandan Mandal

Infectious Disease and Immunology Division, Indian Institute of Chemical
Biology, A Unit of Council of Scientific and Industrial Research (CSIR),
4, Raja S. C. Mullick Road, Kolkata 700032, India

Chitra Mandal

Infectious Disease and Immunology Division, Indian Institute of Chemical Biology, A Unit of Council of Scientific and Industrial Research (CSIR), 4, Raja S. C. Mullick Road, Kolkata 700032, India

Juan A. Martínez

Department of Biochemistry, School of Medicine, University of Puerto Rico, Medical Sciences Campus, San Juan 00936-5067, Puerto Rico

Anie Priscilla Masilamani

Department of Medical Chemistry, Biochemistry and Biotechnology, Center of Excellence on Neurodegenerative Diseases, University of Milan, Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Laura Mauri

Department of Medical Chemistry, Biochemistry and Biotechnology, Center of Excellence on Neurodegenerative Diseases, University of Milan, Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Keiko Miyazaki

Department of Molecular Pathology, Aichi Cancer Center, Nagoya 464-8681, Japan

Susmita Mondal

Infectious disease and Immunology Division, Indian Institute of Chemical Biology, 4, Raja S. C. Mullick Road, Kolkata 700032, India

Joseph Moskal

Department of Biomedical Engineering, The Falk Center for Molecular Therapeutics, McCormick School of Engineering and Applied Sciences, Northwestern University, Evanston, IL 60201, USA

Kankana Mukherjee

Infectious Disease and Immunology Division, Indian Institute of Chemical Biology, 4, Raja S. C. Mullick Road, Kolkata 700032, India

Wim Nerinckx

Laboratorium voor Eiwitbiochemie en Eiwitengineering, Ghent University, K. L. Ledeganckstraat 35, B-9000 Gent, Belgium

Valentina Nocco

Department of Medical Chemistry, Biochemistry and Biotechnology, Center of Excellence on Neurodegenerative Diseases, University of Milan, Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Katsuyuki Ohmori

Department of Clinical Pathology, Kyoto University School of Medicine, Kyoto 606-8501, Japan

Caroline M. Oliveira

Department of Biochemistry, School of Medicine, University of Puerto Rico, Medical Sciences Campus, San Juan 00936-5067, Puerto Rico

Tai-Long Pan

School of Traditional Chinese Medicine, Chang Gung University,
Tao-Yuan, Taiwan

Willy J. Peumans

Laboratory of Biochemistry and Glycobiology, Department of Molecular
Biotechnology, Ghent University, Coupure Links 653, 9000 Gent, Belgium

Robert A. Pon

Institute for Biological Sciences, National Research Council of Canada,
Ottawa, ON KIA 0R6, Canada

Alessandro Prinetti

Department of Medical Chemistry, Biochemistry and Biotechnology,
Center of Excellence on Neurodegenerative Diseases, University of Milan,
Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Simona Prioni

Department of Medical Chemistry, Biochemistry and Biotechnology,
Center of Excellence on Neurodegenerative Diseases, University of Milan,
Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Prakash Radhakrishnan

Department of Biochemistry and Molecular Biology, College of Medicine
Eppley Institute for Research in Cancer and Allied Diseases, University
of Nebraska Medical Center, Omaha, NE 68198-5870, USA

Pierre Rougé

Surfaces Cellulaires et Signalisation chez les Végétaux, UMR UPS-CNRS
5546, 24 Chemin de Borde Rouge, 31326 Castanet, Tolosan, France

Jun Saegusa

Department of Dermatology, University of California, 3301 C Street, Suite 1400
Sacramento, CA 95816, USA

Subiman Saha

Department of Biochemistry, School of Medicine, University of Puerto Rico,
Medical Sciences Campus, San Juan 00936-5067, Puerto Rico

Keiichi Sakuma

Department of Molecular Pathology, Aichi Cancer Center, Nagoya 464-8681, Japan

Aurymar Sánchez

Department of Anatomy and Cell Biology, School of Medicine,
Universidad Central del Caribe, Bayamón 00960-6032, Puerto Rico

Chihiro Sato

Bioscience and Biotechnology Center, Nagoya University, Nagoya, Japan 464-8601

Toshinori Sato

Department of Biosciences and Informatics, Keio University, Hiyoshi,
Yokohama, Japan 223-8522

Roland Schauer

Biochemisches Institut, Christian-Albrechts-Universität, Olshausenstr. 40,
D-24098 Kiel, Germany

Dieter Schouppe

Department of Molecular Biotechnology, Laboratory of Biochemistry
and Glycobiology, Ghent University, Coupure Links 653, 9000 Gent, Belgium

Reinhard Schwartz-Albiez

Tumor Immunologie Programm, Deutsches Krebsforschungszentrum Heidelberg,
Im Neuenheimer Feld 580, D-69120 Heidelberg, Germany

Hans-Christian Siebert

Faculty of Veterinary Medicine, Institute of Physiological Chemistry,
Ludwig-Maximilians-University Munich, Veterinärstr. 13,
80539 Munich, Germany

Tanuja Singh

Glyco-Immunochemistry Research Laboratory, Institute of Molecular and Cellular
Biology, College of Medicine, Chang-Gung University, Kwei-San, Tao-Yuan 333,
Taiwan;

Faculty of Veterinary Medicine, Institute of Physiological Chemistry, Ludwig-
Maximilians-University Munich, Veterinärstr. 13, 80539 Munich, Germany

David F. Smith

Department of Biochemistry, Emory University School of Medicine, Atlanta,
GA 30322, USA

Sandro Sonnino

Department of Medical Chemistry, Biochemistry and Biotechnology,
Center of Excellence on Neurodegenerative Diseases, University of Milan,
Via Fratelli Cervi 93, Segrate, Milano 20090, Italy

G. Vinayaga Srinivasan

Biochemisches Institut, Christian-Albrechts-Universität, Olshausenstr. 40,
D-24098 Kiel, Germany

Pamela Stanley

Department of Cell Biology, Albert Einstein College of Medicine, New York,
NY 1046, USA

Dvora Sudakevitz

The Mina & Everard Goodman Faculty of Life Sciences, Bar-Ilan University,
Ramat-Gan 52900, Israel

Yasuo Suzuki

Department of Biomedical Sciences, College of Life and Health Sciences,
Chubu University, 1200 Matsumoto-cho, Kasugai-shi 487-8501, Aichi, Japan

Noriko Takahashi

Graduate School of Pharmaceutical Sciences, Nagoya City University,
Tanabe-dori 3-1, Mizuho-ku, Nagoya 467-8603, Japan

José J. Tavárez

Department of Biochemistry, School of Medicine, University of Puerto Rico,
Medical Sciences Campus, San Juan 00936-5067, Puerto Rico

Susan N. Thomas

Department of Chemical and Biomolecular Engineering, The Johns Hopkins
University, Baltimore, MD 21218, USA

Chao-Ming Tsai

Center for Biologics Evaluation and Research, Food and Drug Administration,
Rockville, MD, USA

Seigo Usuki

Institute of Molecular Medicine and Genetics, Medical College of Georgia,
Augusta, GA 30912, USA;
Institute of Neuroscience, Medical College of Georgia, Augusta, GA 30912, USA

Manuela Valsecchi

Department of Medical Chemistry, Biochemistry and Biotechnology,
Center of Excellence on Neurodegenerative Diseases, University of Milan,
Via Fratelli Cervi 93, 20090 Segrate, Milano, Italy

Els J.M. Van Damme

Laboratory of Biochemistry and Glycobiology, Department of Molecular
Biotechnology, Ghent University, Coupure Links 653, 9000 Gent, Belgium

Gianni Vandenborre

Laboratory of Biochemistry and Glycobiology, Department of Molecular
Biotechnology, Ghent University, Coupure Links 653, 9000 Gent, Belgium

Cheng-Chung Wang

Department of Chemistry, National Tsing Hua University, Hsinchu 300, Taiwan;
Chemical Biology and Molecular Biophysics Program, Taiwan International
Graduate Program, Academia Sinica, Taipei 115, Taiwan

Pei-Weng Wang

Chang Gung Molecular Medicine Center, Chang Gung University,
Tao-Yuan, Taiwan

Pu Wang

Laboratory of Tumor Biology and Glycobiology, Shenyang Pharmaceutical
University, Shenyang 110016, People's Republic of China;
Department of Life Sciences, Laboratory of Biochemistry,
Shenyang Pharmaceutical University, Shenyang 110016, People's Republic of China

Xiaodong Wang

Laboratory of Tumor Biology and Glycobiology, Shenyang Pharmaceutical University, Shenyang 110016, People's Republic of China

Suzannah A. Williams

Department of Physiology, Anatomy, and Genetics, University of Oxford, Le Gros Clark Building, South Parks Road, Oxford, OX1 3QX, UK

Michaela Wimmerova

Department of Biochemistry, Masaryk University, Kotlarska 2, Brno 61137, Czech Republic

Dirk Wipfler

Tumor Immunologie Programm, Deutsches Krebsforschungszentrum Heidelberg, Im Neuenheimer Feld 580, D-69120 Heidelberg, Germany

Albert M. Wu

Glyco-Immunochemistry Research Laboratory, Institute of Molecular and Cellular Biology, College of Medicine, Chang Gung University, Kwei-san, Tao-yuan 333, Taiwan

June H. Wu

Glyco-Immunochemistry Research Laboratory, Institute of Molecular and Cellular Biology, College of Medicine, Chang-Gung University, Kwei-Shan, Tao-Yuan 333, Taiwan

Ming-Fang Wu

Department and Institute of Microbiology and Immunology, National Yang-Ming University, Taipei, Taiwan

Peixing Wu

Department of Biosciences and Informatics, Keio University, Hiyoshi, Yokohama, Japan 223-8522

Shih-Hsiung Wu

Institute of Biological Chemistry, Academia Sinica, Taipei 115, Taiwan

Sadako Yamagata

Laboratory of Tumor Biology and Glycobiology, Shenyang Pharmaceutical University, Shenyang 110016, People's Republic of China

Tatsuya Yamagata

Laboratory of Tumor Biology and Glycobiology, Shenyang Pharmaceutical University, Shenyang 110016, People's Republic of China

Feng-Ling Yang

Institute of Biological Chemistry, Academia Sinica, Taipei 115, Taiwan

Ri-Yao Yang

Department of Dermatology, University of California, 3301 C Street, Suite 1400, Sacramento, CA 95816, USA

Yu-Liang Yang

Institute of Biological Chemistry, Academia Sinica, Taipei 115, Taiwan

Zhangung Yang

Glyco-Immunochemistry Research Laboratory, Institute of Molecular and Cellular Biology, College of Medicine, Chang-Gung University, Kwei-San, Tao-Yuan 333, Taiwan

Robert K. Yu

Institute of Molecular Medicine and Genetics and Institute of Neuroscience, Medical College of Georgia, Augusta, GA 30912, USA

Jinghai Zhang

Department of Life Sciences, Laboratory of Biochemistry, Shenyang Pharmaceutical University, Shenyang 110016, People's Republic of China

Keren D. Zinger-Yosovich

The Mina & Everard Goodman Faculty of Life Sciences, Bar-Ilan University, Ramat-Gan 52900, Israel

Wei Zou

Institute for Biological Sciences, National Research Council of Canada, Ottawa, ON KIA 0R6, Canada

Medel Manuel L. Zulueta

Department of Chemistry, National Tsing Hua University, Hsinchu 300, Taiwan