

glycans

glycans are complex carbohydrates that play a critical role in various biological processes across all living organisms. These sugar chains are found attached to proteins and lipids, influencing molecular stability, cell signaling, and immune responses. Glycans exhibit immense structural diversity, which enables them to mediate specific interactions in cellular communication and pathogen recognition. Understanding glycans and their biosynthesis has become increasingly important in fields such as biomedicine, glycomics, and biotechnology. This article explores the fundamental aspects of glycans, including their classification, biological functions, analytical techniques, and implications in health and disease. The following sections provide a comprehensive overview of glycans, highlighting their significance in molecular biology and therapeutic development.

- What Are Glycans?
- Types and Classification of Glycans
- Biological Functions of Glycans
- Methods for Glycan Analysis
- Glycans in Health and Disease

What Are Glycans?

Glycans are carbohydrate structures composed of monosaccharide units linked by glycosidic bonds. These sugar chains can be linear or branched, varying in length and complexity. In biological systems, glycans commonly attach to proteins (forming glycoproteins) or lipids (forming glycolipids), modifying their properties and functions. The study of glycans falls under the domain of glycoscience, which investigates their synthesis, structure, and biological roles.

Structure and Composition

The structural complexity of glycans arises from the diversity of monosaccharides, linkage types, and branching patterns. Typical monosaccharides involved include glucose, mannose, galactose, fucose, and sialic acid. The linkages between these sugars can be α or β and vary in position, resulting in a vast array of possible structures. This heterogeneity enables glycans to perform highly specific biological functions.

Glycosylation: The Process of Glycan Attachment

Glycosylation is the enzymatic process by which glycans are covalently attached to proteins or lipids. It occurs mainly in the endoplasmic reticulum and Golgi apparatus of cells. There are two primary types of glycosylation: N-linked, where glycans attach to the nitrogen atom of asparagine residues,

and O-linked, where attachment is to the oxygen atom of serine or threonine residues. This modification affects protein folding, stability, and cellular localization.

Types and Classification of Glycans

Glycans can be classified based on their linkage, composition, and biological context. This classification aids in understanding their diverse roles and facilitates research in glycomics and related fields.

N-Linked Glycans

N-linked glycans are attached to the nitrogen atom of asparagine residues within specific consensus sequences. They typically share a common core structure but differ in branching and terminal modifications. N-linked glycans are involved in protein folding quality control and cell-cell interactions.

O-Linked Glycans

O-linked glycans attach to the oxygen atom of serine or threonine residues. Unlike N-linked glycans, they do not have a common core structure and exhibit greater variability. O-linked glycosylation is common in mucins and plays a role in protecting epithelial surfaces and mediating cell signaling.

Other Glycan Types

Beyond N- and O-linked glycans, other types include glycosaminoglycans (GAGs) and glycolipids. GAGs are long, linear polysaccharides involved in extracellular matrix structure and cell communication. Glycolipids consist of glycans linked to lipid moieties and are essential components of cell membranes.

Biological Functions of Glycans

Glycans perform a wide range of biological functions essential for cellular and organismal homeostasis. Their structural diversity allows them to participate in various molecular interactions and biological pathways.

Cell-Cell Communication

Glycans on cell surfaces mediate recognition and adhesion processes between cells. This is crucial during immune responses, embryonic development, and tissue organization. Specific glycan patterns serve as ligands for lectins, which are carbohydrate-binding proteins facilitating these interactions.

Immune System Modulation

Glycans influence the immune system by modulating the activity of immune cells and recognition of pathogens. Certain glycan motifs act as markers for self versus non-self, enabling immune cells to detect and respond to invading microorganisms effectively.

Protein Stability and Function

Attachment of glycans to proteins can enhance their stability, solubility, and resistance to proteolysis. Glycosylation also affects protein folding and trafficking, ensuring proper localization and function within the cell.

Pathogen Interaction and Infection

Many pathogens exploit host glycans to attach and invade cells. Viral, bacterial, and parasitic organisms recognize specific glycan structures on host cell surfaces, facilitating infection. Understanding these interactions is vital for developing therapeutic interventions.

Methods for Glycan Analysis

Analyzing glycans requires specialized techniques due to their structural complexity and heterogeneity. Advances in analytical methods have propelled glycomics, enabling detailed characterization of glycan structures and functions.

Mass Spectrometry

Mass spectrometry (MS) is a powerful tool for determining glycan composition, structure, and attachment sites. Techniques such as MALDI-TOF and LC-MS/MS allow precise analysis of glycan masses and fragmentation patterns, facilitating detailed structural elucidation.

Chromatography Techniques

Chromatographic methods, including high-performance liquid chromatography (HPLC) and gas chromatography (GC), are commonly used to separate glycans based on size, charge, or hydrophobicity. These techniques often precede mass spectrometry analysis for enhanced resolution.

Lectin-Based Assays

Lectins are proteins that specifically bind certain glycan motifs. Lectin arrays and affinity chromatography exploit this specificity to detect and isolate glycans or glycoproteins with defined sugar structures. These methods are valuable for profiling glycan patterns on cells and proteins.

Nuclear Magnetic Resonance (NMR) Spectroscopy

NMR spectroscopy provides detailed information on glycan structure and conformation in solution. Although less sensitive than MS, NMR can reveal linkage positions and stereochemistry, contributing to comprehensive glycan characterization.

Glycans in Health and Disease

Glycans are integral to maintaining health, and alterations in glycosylation patterns are associated with numerous diseases. Studying these changes offers insights into disease mechanisms and potential therapeutic targets.

Cancer and Glycan Alterations

Tumor cells often exhibit abnormal glycosylation, including increased branching and sialylation of glycans. These changes can promote tumor progression, metastasis, and immune evasion. Glycan biomarkers are increasingly used in cancer diagnosis and prognosis.

Congenital Disorders of Glycosylation

Genetic defects affecting glycan biosynthesis or processing lead to congenital disorders of glycosylation (CDGs). These rare diseases manifest with diverse symptoms, including developmental delays and immune deficiencies, underscoring the essential role of glycans in human physiology.

Infectious Diseases

Pathogens manipulate host glycans to facilitate infection. Conversely, host glycan modifications can influence susceptibility to infection and immune response. Therapeutic strategies targeting glycan-mediated interactions are under development to combat infectious diseases.

Therapeutic Applications

Glycan engineering enhances the efficacy and safety of biopharmaceuticals, such as monoclonal antibodies and vaccines. Modifying glycosylation patterns can improve drug stability, reduce immunogenicity, and enhance therapeutic activity.

- Glycomics technologies enable comprehensive glycan profiling.
- Glycan-based biomarkers support disease diagnosis and monitoring.
- Glycan-targeted drugs offer novel treatment avenues.
- Understanding glycans is crucial for advancing personalized medicine.

Frequently Asked Questions

What are glycans and why are they important in biology?

Glycans are complex carbohydrates composed of sugar molecules linked together. They play crucial roles in various biological processes including cell-cell communication, immune response, and protein folding.

How do glycans influence protein function?

Glycans attached to proteins (glycoproteins) affect protein folding, stability, and activity. They can modulate protein interactions and localization, influencing cellular signaling and immune recognition.

What techniques are used to analyze glycans?

Common techniques for glycan analysis include mass spectrometry, high-performance liquid chromatography (HPLC), lectin arrays, and nuclear magnetic resonance (NMR) spectroscopy.

What is glycosylation and its significance?

Glycosylation is the enzymatic process that attaches glycans to proteins or lipids. This modification is essential for proper protein function, cell signaling, and immune system regulation.

How do glycans impact human health and disease?

Altered glycan structures are associated with diseases such as cancer, autoimmune disorders, and infectious diseases. Glycan patterns can serve as biomarkers for diagnosis and targets for therapy.

What are N-linked and O-linked glycans?

N-linked glycans attach to the nitrogen atom of asparagine residues in proteins, while O-linked glycans bind to the oxygen atom of serine or threonine residues. Both types influence protein properties differently.

Can glycans be targeted for drug development?

Yes, glycans and glycan-processing enzymes are promising targets for drug development, especially in cancer therapy, infectious disease treatment, and immunomodulation.

What role do glycans play in viral infections?

Viruses often exploit host glycans to enter cells and evade immune detection. Understanding viral glycan interactions helps in designing antiviral drugs and vaccines.

How is glycomics advancing our understanding of glycans?

Glycomics, the comprehensive study of glycans, uses advanced analytical technologies to map glycan structures and functions, enhancing insights into their biological roles and disease relevance.

Additional Resources

1. *Essentials of Glycobiology*

This comprehensive textbook provides a foundational understanding of the structure, biosynthesis, and function of glycans. It covers the roles of glycans in cell signaling, immune response, and disease mechanisms. Ideal for students and researchers new to glycobiology, the book combines detailed illustrations with current research insights.

2. *Glycans in Biotechnology and Drug Development*

Focusing on the application of glycans in therapeutic design, this book explores the development of glycan-based drugs and diagnostic tools. It discusses glycoengineering techniques and the impact of glycosylation on protein stability and efficacy. The text is valuable for biotechnologists and pharmaceutical scientists.

3. *Structural Glycobiology: Methods and Protocols*

This volume provides detailed experimental protocols for studying glycan structures using various biochemical and biophysical techniques. It includes methods such as mass spectrometry, NMR spectroscopy, and chromatography for glycan analysis. Researchers looking to implement or refine glycan characterization techniques will find this guide indispensable.

4. *The Role of Glycans in Infectious Diseases*

Exploring the interface between glycobiology and microbiology, this book examines how pathogens exploit host glycans for infection and immune evasion. It reviews glycan-related mechanisms in viral, bacterial, and parasitic diseases. The text offers insights into novel therapeutic strategies targeting glycan interactions.

5. *Glycomics: From Fundamentals to Clinical Applications*

Covering the rapidly advancing field of glycomics, this book introduces high-throughput technologies for glycan profiling and their clinical relevance. It discusses biomarker discovery and the role of glycan alterations in cancer and autoimmune diseases. Clinicians and researchers interested in translational glycobiology will find this resource valuable.

6. *Glycan Engineering in Cell Biology and Therapeutics*

This book details genetic and enzymatic methods to modify glycan structures on cells and proteins. It highlights applications in improving cell therapies, vaccine development, and regenerative medicine. The text is geared toward molecular biologists and bioengineers working in glycoengineering.

7. *Computational Glycobiology: Modeling and Simulation*

Focusing on the computational approaches to study glycans, this book covers molecular modeling, docking, and dynamics simulations of glycan-protein interactions. It provides practical examples and software recommendations for researchers. This resource bridges the gap between experimental glycobiology and bioinformatics.

8. *Glycans and Immune Regulation*

This text explores the critical roles of glycans in modulating immune cell functions and inflammatory

responses. It discusses glycan-mediated signaling pathways and their implications in autoimmune diseases and cancer immunotherapy. Immunologists and glycobiologists will benefit from the detailed analysis provided.

9. *Advances in Glycoscience: Chemical and Biological Perspectives*

A collection of recent research articles and reviews, this book presents cutting-edge developments in glycan chemistry and biology. Topics include novel synthetic methods, glycan-protein interactions, and emerging therapeutic applications. It serves as an excellent reference for advanced researchers seeking to stay current in the field.

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glycans: The Role of Glycans in Immune Cell Functions Jasmeen S. Merzaban, Monica M. Burdick, Charles J. Dimitroff, 2020-05-26 Glycans represent a major constituency of post-translational modifications that occur on most, if not all, proteins. Whether on mammalian or invertebrate cell surfaces, they exist as sugar chain moieties designed from the exquisite and coordinated activity of cell-specific glycosylation. Some of the more common glycan structures are linked to cell surface polypeptides via an asparagine (N)-linked residue or a serine/threonine (O)-linked residue, along with a notable contingent found linked to ceramides in the lipid bilayer known as glycosphingolipids. These glycans can associate with complementary glycan-binding proteins (GBP) or lectins to mediate and translate this carbohydrate recognition to cell function. In immunity, there is increasing evidence that precise immune cell glycans are recognized by corresponding GBPs in a cell-intrinsic or -extrinsic manner. Unique carbohydrate recognition domains within GBPs are comprised of precisely spaced amino acid functional groups that allow for selective engagement of a particular glycan target. This structure-function relationship is present in immune signaling pathways, whereby glycans and GBPs on the surface of immune cells (and non-immune cells) help control processes such as immune cell activation, recognition of pathogens, suppression and tissue-specific migration. The diversity of glycan structures and glycosylation among individual immune cell subsets is controlled by the expression of genes involved in glycan biosynthesis including glycosyltransferases, glycosidases, glycan-precursor biosynthetic enzymes and nucleotide-sugar transporters. These genes represent more than 3% of the human genome, and cell-specific expression of these genes dictates a cell's glycan repertoire, ultimately influencing its molecular interactions with GBPs. Altogether, these emerging lines of investigation highlight the regulatory capacity of glycans in immune health and disease, which in turn, pave the way for novel diagnostic, prognostic, and therapeutic strategies.

glycans: Plant Glycobiology - A Sweet World of Glycans, Glycoproteins, Glycolipids, and Carbohydrate-Binding Proteins Els J. M. Van Damme, Georg J. Seifert, Richard Strasser, 2021-10-21

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studies the synthesis, structure, function, regulation, and evolution of glycans and glycan-binding molecules. Glycans are synthesized and added as modifications to proteins, lipids, and RNA. Though they are often associated with functions outside of cells (glycoproteins and glycolipids are most often extracellular or secreted), glycans are also active within cells. Glycans are known to have diverse physiological roles ranging from cell adhesion (maintaining tissue structure and integrity) to molecular recognition (marking position during development, or self-identity in immunity and reproduction). Glycans also regulate cellular activity and physiological state. The families of proteins that bind glycans are called lectins. Glycans and lectins are vital in many diseases such as cancer, neurodegeneration, inflammation, allergies, asthma, and autoimmune disorders.

glycans: Sugar Chains Tadashi Suzuki, Kazuaki Ohtsubo, Naoyuki Taniguchi, 2015-02-02 This book presents the latest breakthrough results in glycobiology regarding the roles of glycans in relation to quality control and transport of protein, the immune system, viral infection, stem cells, the neural system, and various diseases such as cancer, diabetes, chronic obstructive pulmonary disease, muscular dystrophy, and schizophrenia. Although glycoscience has long been regarded as a very specialized field with no simple analytical method, the recent explosive progress in research continues to provide limitless evidence that glycan chains are the key component in various biological phenomena. Cell surface glycans, for example, change with developmental stages or environmental conditions and thus represent a “face” of the cell that is utilized for identification of iPS and ES cells and as biomarkers in diagnosis or detection of cancer. This book comprises 17 chapters, each of which poses outstanding “glyco-related” questions enabling non-specialists to have a clearer idea about what the future direction for further investigation of glycans in their own research fields will be. Also including basic information to understand the nature of glycans, this title serves as an excellent “textbook” for researchers in diverse research fields who are not familiar with, but nevertheless interested in, glycan chains or sugar chains.

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glycans: Plant Glycobiology - a sweet world of lectins, glycoproteins, glycolipids and glycans Els J. M. Van Damme, Nausicaä Lannoo, Cécile Albenne, Elisabeth Jamet, 2015-02-12 Plants synthesize a wide variety of unique glycan structures which play essential roles during the life cycle of the plant. Being omnipresent throughout the plant kingdom, ranging from simple green algae to modern flowering plants, glycans contribute to many diverse processes. Glycans can function as structural components in the plant cell wall, assist in the folding of nascent proteins, act as signaling molecules in plant defense responses or (ER) stress pathways, or serve within the energy metabolism of a plant. In most cases, glycans are attached to other macromolecules to form so-called glycoconjugates (e.g. glycoproteins, proteoglycans and glycolipids), but they can also be present as free entities residing in the plant cell. Next to the broad, complex set of glycans, plants also evolved an elaborate collection of lectins or proteins with a lectin-like domain, which can recognize and bind to endogenous (plants-own) or exogenous (foreign) glycans. Though still poorly understood in plants, the dynamic interactions between lectins and carbohydrate structures are suggested to be involved in gene transcription, protein folding, protein transport, cell adhesion, signaling as well as defense responses. As such, a complex and largely undetermined glycan-interactome is established inside plant cells, between cells and their surrounding matrix, inside the extracellular matrix, and even between organisms. Studying the biological roles of plant glycans will enable to better understand plant development and physiology in order to fully exploit plants for food, feed and production of

pharmaceutical proteins. In this Research Topic, we want to provide a platform for articles describing the latest research, perspectives and methodologies related to the fascinating world of plant glycobiology, with a focus on following subjects: 1. Identification and characterization of plant glycans, their biosynthetic and degradation enzymes 2. Characterization of plant lectins and glycoproteins 3. Plant glycans in the plant's energy metabolism 4. Role of plant glycans in plant defense signaling 5. Use of plant lectins in pest control 6. Plant lectins as new tools in human medicine 7. Glyco-engineering in plants

glycans: Human Antibodies Against The Dietary Non-Human Neu5Gc-carrying Glycans in Normal and Pathologic States Jean Paul Soulillou, Vered Padler-Karavani, 2020-10-28 This eBook is a collection of articles from a Frontiers Research Topic. Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area! Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers Editorial Office: frontiersin.org/about/contact.

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Beginning with analytic approaches and bioinformatics, this work provides a detailed discussion of relevant databases, data integration, and analysis. It then moves on to a discussion of specific model organism and pathogen glycomes followed by therapeutic approaches to human disorders of glycosylation. Structure and function of glycomes are included along with state-of-the-art technologies and systems approaches to the analysis of glycans. - Synthesizes contributions from experts in biology, chemistry, bioinformatics, biotechnology, and medicine - Highlights chapters devoted to chemical synthesis, cancer glycomics and immune cell glycomics - Includes discussions of proteomics, mass spectrometry, NMR, array technology, and transcriptomics analytic approaches

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chromatography (SFC). Thirty-one chapters cover: various modes of HPLC, CE, CEC, FFF, GC and SFC that are currently applied to the analysis of carbohydrates; discussions on analytical and preparative separations; descriptions of the principles of detection and quantitative determination of carbohydrates by the various separation techniques; reviews of sample preparations; and information on important applications. Furthermore, the book describes in detail the different direct and indirect detection methods that have been introduced for the sensitive detection of carbohydrates. This title is useful for a wide audience including separation scientists; analytical chemists and biochemists; carbohydrate chemists; glycoprotein and glycolipid chemists; molecular biologists; and biotechnologists. The book is also a useful reference for both the experienced analyst and the newcomer and for users of modern chromatography and electrophoresis. Contains 31 chapters covering all aspects of carbohydrate analysis by modern chromatography and electrophoresis. Each chapter discusses the basic principles, advantages and limitations, and applications of the particular detection technique. Useful reference for both the experienced analyst and the newcomer.

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chromatography. The text gives those working in academia and industry the opportunity to learn, refresh, and deepen their understanding of the field by covering basic and advanced theoretical concepts, recognition mechanisms, conventional and advanced instrumentation, method development, data analysis, and more. This third edition addresses new developments in the field with updated chapters from expert researchers. The book is a valuable reference for research scientists, teachers, university students, industry professionals in research and development, and quality control managers. - Emphasizes the integration of chromatographic methods and sample preparation - Provides important data related to complex matrices, sample preparation, and data handling - Covers the most interesting and valuable applications in different fields, e.g., proteomic, metabolomics, foodomics, pollutants and contaminants, and drug analysis (forensic, toxicological, pharmaceutical, biomedical) - Offers comprehensive updates to all chapters - Adds new chapters on selection of liquid chromatographic mode, proteomics, doping analysis, analysis of microplastics, and analysis of pharmaceutically and biologically relevant isoforms

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