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A BRIEF REVIEW ON GLYCOMIMETICS AND THEIR PHARMACEUTICAL APPLICATIONS

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ABSTRACT: This review enumerates the classification, role, and importance of carbohydrate derivatives and glycomimetics. Carbohydrates are polyhydroxy aldehydes or ketones. Carbohydrates are the most abundant dietary source of energy for all organisms. They are precursors for many organic compounds such as fatty acids and amino acids. They can participate in the structure of cell membranes and cellular functions such as cell growth, adhesion, and fertilization. Glycomimetics are the compounds of low molecular weight based on the structure of functional carbohydrates. The rational style of tiny molecule glycomimetics that exhibit improved drug-like properties like enlarged affinity, blood serum half-life, stability, and bioavailability. Currently, two successful drugs for influenza (Tamiflu, Relenza) are mimicking (Glycomimetics) the transition state of the enzymatic cleavage of the terminal N-acetyl neuraminic acid. A hopeful example is the antibody 2G12, which has been shown to neutralize HIV infectivity. The functional carbohydrates identified in these recognition processes themselves do not make good drug candidates. Rather, their bioactive conformations in their receptor sites can be empirically determined by physicochemical methods and used for the rational design of small molecule mimics (Glycomimetics) that have higher affinities and more drug-like properties of long serum half-life, metabolic stability, low toxicity, and oral bioavailability. These glycomimetics drugs are new chemical entities and provide innovative therapeutic strategies to address current unmet needs among a wide spectrum of disease applications.

INTRODUCTION: Compounds of low molecular weight based on the structure of functional carbohydrates. These molecules are called glycomimetics [1].

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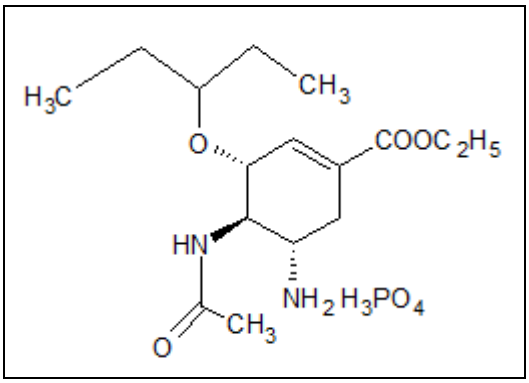
"The role of membrane glycol conjugates in a variety of pharmacologically relevant recognition phenomena has stimulated interest in the synthesis and biological evaluation of analogs of carbohydrates, defined as glycomimetics" [2].

The rational style of little molecule glycomimetics that exhibit improved drug-like properties like inflated affinity, body fluid half-life, stability, and bioavailability. Currently, two successful drugs for influenza (Tamiflu, Relenza) are mimicking (glycomimetics) the transition state of the

enzymatic cleavage of the terminal N-acetyl neuraminic acid [1].



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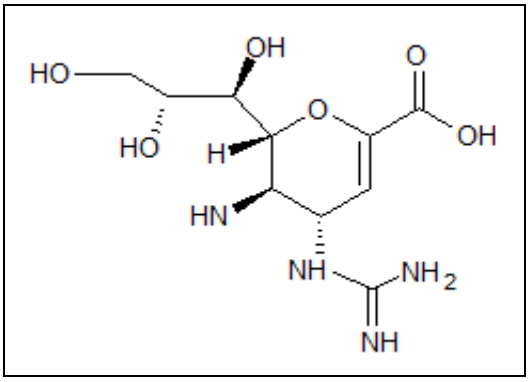


RELENZA

A hopeful example is that the protein 2G12, that has been shown to neutralize HIV infectivity. It binds to a typical supermolecule epitope on the HIV coat supermolecule gp120. Glycomimetics would permit it to make the most this substrate modification and have the potential to provide a glycomimetics conjugate vaccinum with broad neutralizing activity towards HIV infection. The primary step within the rational style of a glycomimetics drug is to completely perceive the molecular base of the interaction between the purposeful supermolecule epitopes and its super-molecule receptor (lectins). Soluble proteins, like lectins, toxins and antibodies, additionally bind cell surface carbohydrates and exhibit a basic role in several diseases [3].

Lectins: Lectins might arise from pathogens, like the virulence factors (PA-IL and PA-IIL) of *Pseudomonas aeruginosa*, which aid infection and virulence of the microorganism or they're endogenous in humans and play important roles in human sickness. Over eighty human lectins are known however solely a little portion thence has been studied intimately **Table 1** [4].

TABLE 1: FAMILIES OF HUMAN CARBOHYDRATE-BINDING PROTEINS (LECTINS) [3]

Intracellular Lectins	Extracellular Lectins
L-type lectins (β-sandwich)	C-type lectins (unique α/β selectins)
DC-Sign	
Asialoglycoprotein receptor	
Dectins	
Mannose-binding macromolecule	I-type lectins (Siglecs, Igsuper family)
P-type lectins (unique β-rich)	R-type lectins (β-trefoil)
Calnexin	Galectins (β-sandwich)

Incorporation of moieties that enhance binding to humor liquid body substance macromolecules will increase the serum half-life of a glycomimetics by victimization serum protein to act as a sink or reservoir at intervals the blood. If the glycomimetics area unit being eliminated from the blood by a lively transport system (*i.e.*, organic ion transport OAT1), the location recognized by the elimination system will either be removed if global organization vital, or replaced with a bio isostere, thereby maintaining activity of the glycomimetics however obstruction the power to be recognized by the transport / elimination system [5]. Knowing the bioactive conformation conjointly provides the data necessary to style glycomimetics within which this conformation is pre-organized already in answer resulting in reduced entropy prices upon binding.

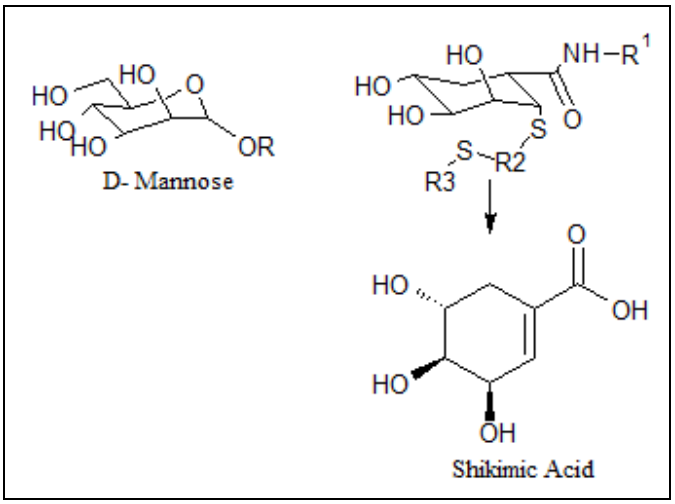


FIG. 1: STRATEGY FOR INHIBITOR DESIGNS

Chemistry of Glycomimetics: Shikimic acid is often reworked into monovalent and multivalent glycomimetics that concentrate on totally different members of the C-type lectin class, together with DC-SIGN (Dendritic cell specified living thing adhesion molecule-3-grabing non-integrin), adendritic cell lectins that facilitate HIV

transmission [6]. C-type lectins area unit an oversized category of proteins that area unit integrated to the immune perform system. Named for his or her dependence on metallic element ions for saccharide complexation, these lectins typically bind to mannosides. In these complexes, the 2-, 3- and chemical group teams of mannose contribute to binding.

D-Mannose **Fig. 1** and a substructure of the binding site of a posh of mannose and MBP-A (bottom) (PDB accession code 1KWY9). The chemical group teams necessary for the recognition of lectins. hydroxyl radical arrangement to afford glycomimetics [7], compounds that mimic shikimic acid was reworked into compounds with the mandatory arrangement of chemical group teams, from that inhibitors were known of an epitome C-type glycoprotein, mannose-binding macro-molecule A (MBP-A) [8]. DC-SIGN binds decrepit to simple sugar ligands like N-acetyl amine and L-fructose. The affinity for oligosaccharides is slightly higher. Solid part synthesis is employed to seek out the glycomimetics from a library of purported mannose mimics **Fig. 2** [9].

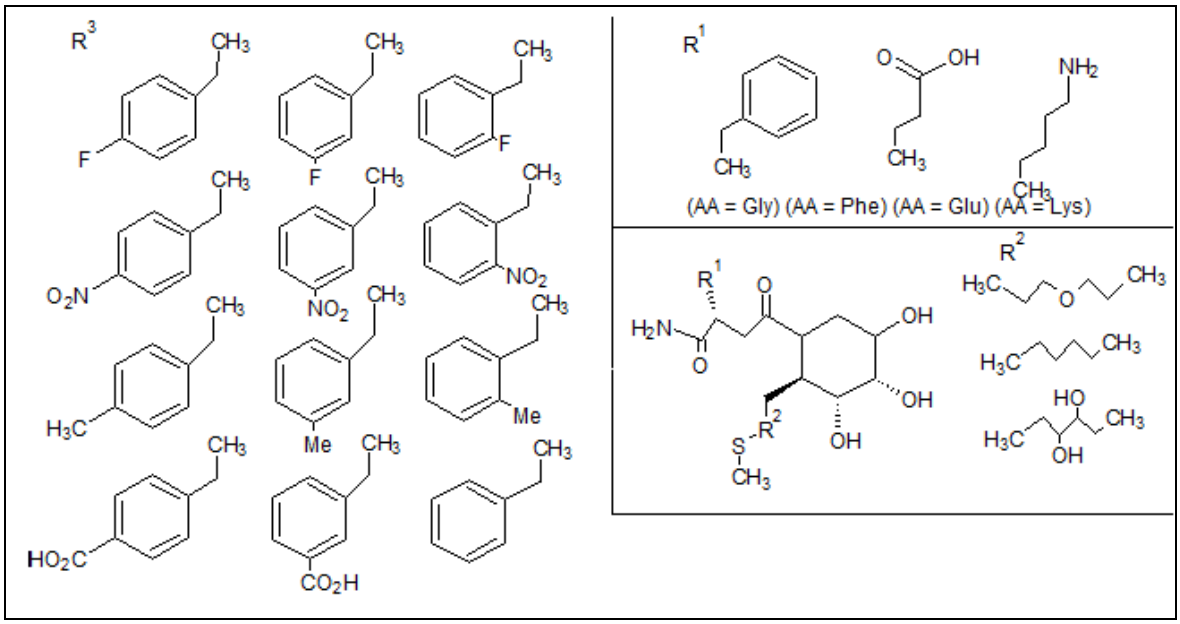


FIG. 2: FEATURES OF THE GLYCOMIMETICS LIBRARY TARGETING DC-SIGN

So, it's gratifying that the DC-SIGN inhibitors square measure superior to famous monosaccharide ligands. The results, therefore, offer a place to begin for optimizing substance efficiency. Most importantly, they support the generality of style an equivalent scaffold is accustomed to generate ligands for 2 lectins with completely different binding sites [8].

A technique, multivalent substance synthesis involves the applying of a ring-opening metathesis chemical process (ROMP). This technique will yield polymers of outlined lengths that operate like extremely effective biological probes [10, 11-15], in addition, ROMP generated polymers will promote receptor clustering [16], and this property may facilitate the investigations of DC-SIGN mediated learning. Finally, ROMP will bring about to polymers of outlined length with poly disparity indices (PDIs) close to unity. In summary, ROMP affords products with valuable attributes. The multivalent glycomimetics were generated from compound backbones bearing succinimide esters, that might be changed post-polymerization [17] to append the glycomimetics epitopes, to come up with polymers that bind avidly to DC-SIGN, the length of the compound should be decent for it to interact in multivalent binding, *i.e.*, either occupies multiple binding sites among the tetrameric DC-SIGN or cluster.

In summary, the shikimic acid-derived glycomimetics scaffolds are often wont to generate ligands for C-type lectins. This approach will yield inhibitors that are selective and potent. Each MBP-A and DC-SIGN possess considerably completely different binding sites, revealing the final utility of the approach for targeting numerous lectins to boot,

conversion of a lead glycomimetics into a multivalent substance yields a potent non-carbohydrate substance of DC-SIGN. During this means, multivalence is often exploited to come up with extremely effective non-macromolecule inhibitors of lectins that are vital for human health [18].

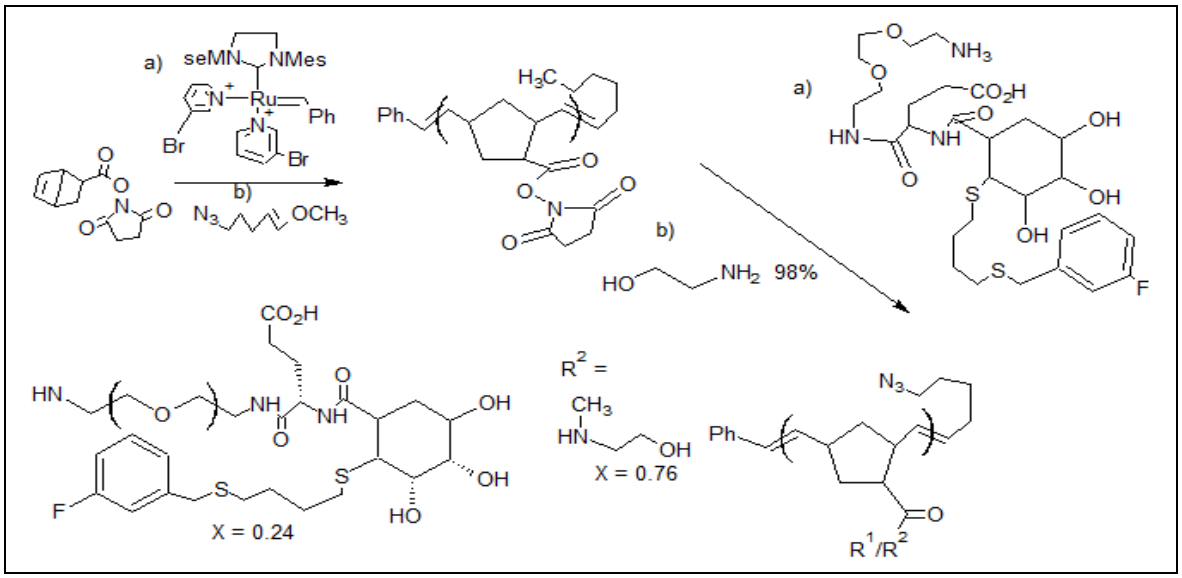


FIG. 3: NON CARBOHYDRATE INHIBITORS OF DC-SIG

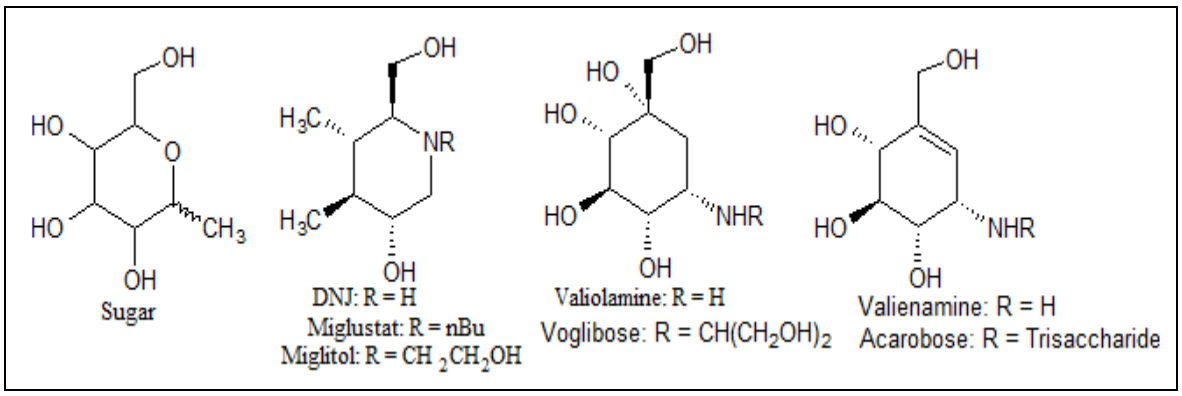


FIG. 4: NON GLYCOSIDASE INHIBITORS OF LECTINS

Glycosidase inhibitors with numerous structures, imino sugars or amino cyclitols and carbasugars are ready. Among them, miglitol and voglibose are employed in non-insulin dependent polygenic disorder treatment. The synthesis **Fig. 3** and **Fig. 4** of potential glycosidase inhibitors, we targeted on the access to membered carbasugars and connected amino cyclitols to review the result of the improved flexibility and of the new abstraction distribution of the radical teams displayed by these structures on their ability within the situation of the accelerator [19].

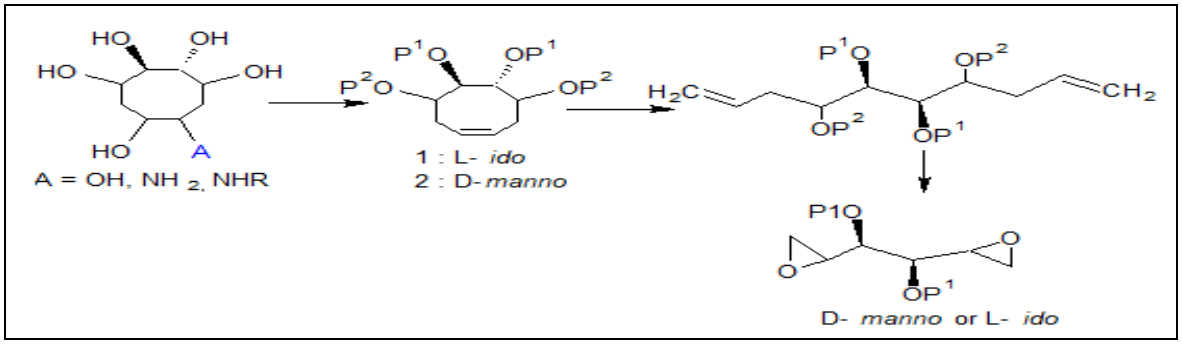


FIG. 5: EIGHT FUSED SUGAR ALCOHOL DERIVATIVES

Based on a key step of carbo cyclization **Fig. 5** by ring-closing metathesis involving a one, 9-diene, simply out there from the C2- symmetrical D-mannose or L-ido-bis-epoxide. The artificial potentialities of the fresh created covalent bond within the cyclooctenic structure were then explored to succeed in the targeted Glycomimetics [20]. The mannose receptor may be a monomeric membrane-bound macromolecule displaying eight carbohydrate-recognition domains (CRDs), chiefly expressed on nerve fiber cells and macrophages, being directly concerned within the endolysosomic matter process and presentation pathway [21]. It absolutely was shown that polymannosylation or -fucosylation of matter peptides induce associate degree improved uptake and presentation by the nerve fiber cells. This has been incontestable by victimization *in-vitro* T cell clones proliferation experiments [22, 23].

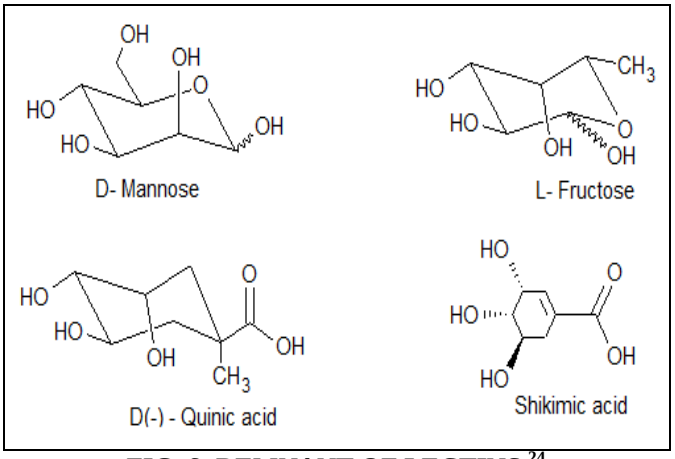


FIG. 6: REMNANT OF LECTINS [24]

Structures of monomeric carbohydrates or glycomimetics recognized by the mannose receptor. A major contribution to the binding is provided by coordination bonds between 2 chemical group teams of the matter (in the open box), a coagulation factor, and 4 residues of the glycol protein. To use of d-(_) - quinic and shikimic acid derivatives clustered on lysinyl trees **Fig. 6**. These acids possess 2 trans-di-equatorial (or pseudodi- equatorial, respectively), section chemical group teams within the (+) - synclinal configuration. As deduced from X-rays crystallographic knowledge [24], collected with the rat mannose-binding glycoprotein that shares similarities with the mannose receptor CRDs, this can be the configuration needed for interaction with the mannose receptor. These commercially offered element compounds were elite not just for their purported mannose mimicry however additionally for his or her chemical stability and their easy fictionalization *via* their acid teams [25].

SAR of Glycomimetics: A set of fluorescein-labeled quinic and shikimic acids-containing clusters along with one, 2, 4 and five were synthesized **Fig. 7** from lysinyl cores and their acquisition was assayed on peripheric blood monocyte-derived human nerve fiber cells by cyto fluorimetry analysis [26]. The mannose receptor capture specificity was more assessed by competitive inhibition experiments, by confocal research analysis and by expression of the mannose receptor in transfected Cos-1 cells [27].

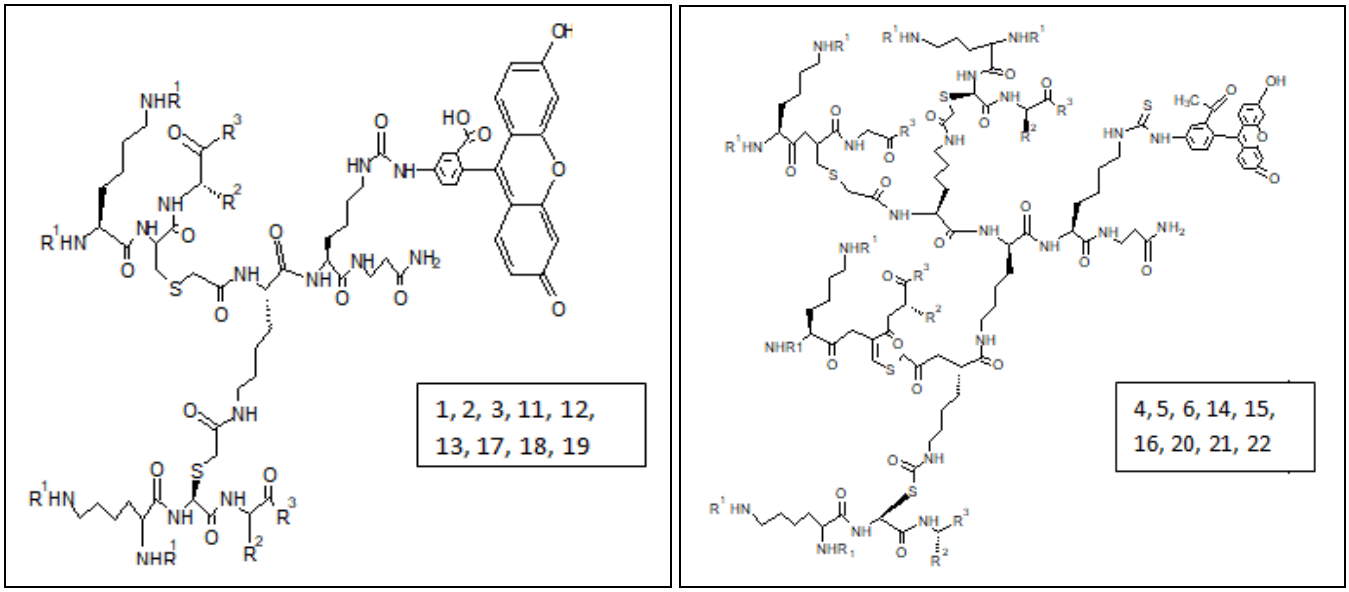
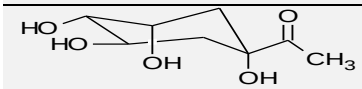
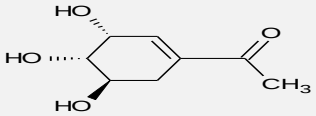
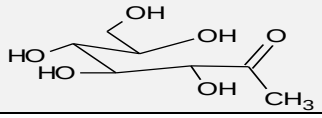


FIG. 7: HYPER BRANCHED CLUMP GLYCOMIMETICS

R^1	R^2	R^3	Compounds
	$(CH_2)_3NH(CH_2{=}NH)NH_2$	OH NH_2 NH_2	1, 4, 11, 14, 17, 20
	$(CH_2)_3NH(CH_2{=}NH)NH_2$	OH NH_2 NH_2	2, 5, 12, 15, 18, 21
	$(CH_2)_3NH(CH_2{=}NH)NH_2$	OH NH_2 NH_2	3, 6, 13, 16, 19, 22

The mimics were evaluated with relevance mannosylated trees, for instance, seven and nine, closely associated with the foremost potent mannose receptor ligands to this point reportable, and to analog constructs, for instance, 3, 6, 8 and 10 embellished with galactonamide or galactoside as positive or negative controls, severally. The latter were designed so as to discriminate the mannose receptor-specific uptake from nonspecific binding to or bodily process of nerve fiber cells. From this study, it appeared that power compounds were poorly internalized and chiefly through nonspecific endocytosis. Otherwise, specific uptake became vital from the power constructs. Acquisition of the power glycomimetics one and a pair of were like the corresponding cluster mannoside. Amazingly, the capture was higher for the power trees than for the octavalent ones four or five whereas, the mannosylated series **Fig. 8**, it was systematically increased with increasing valency [28]. The discovered divergence could originate from variations.

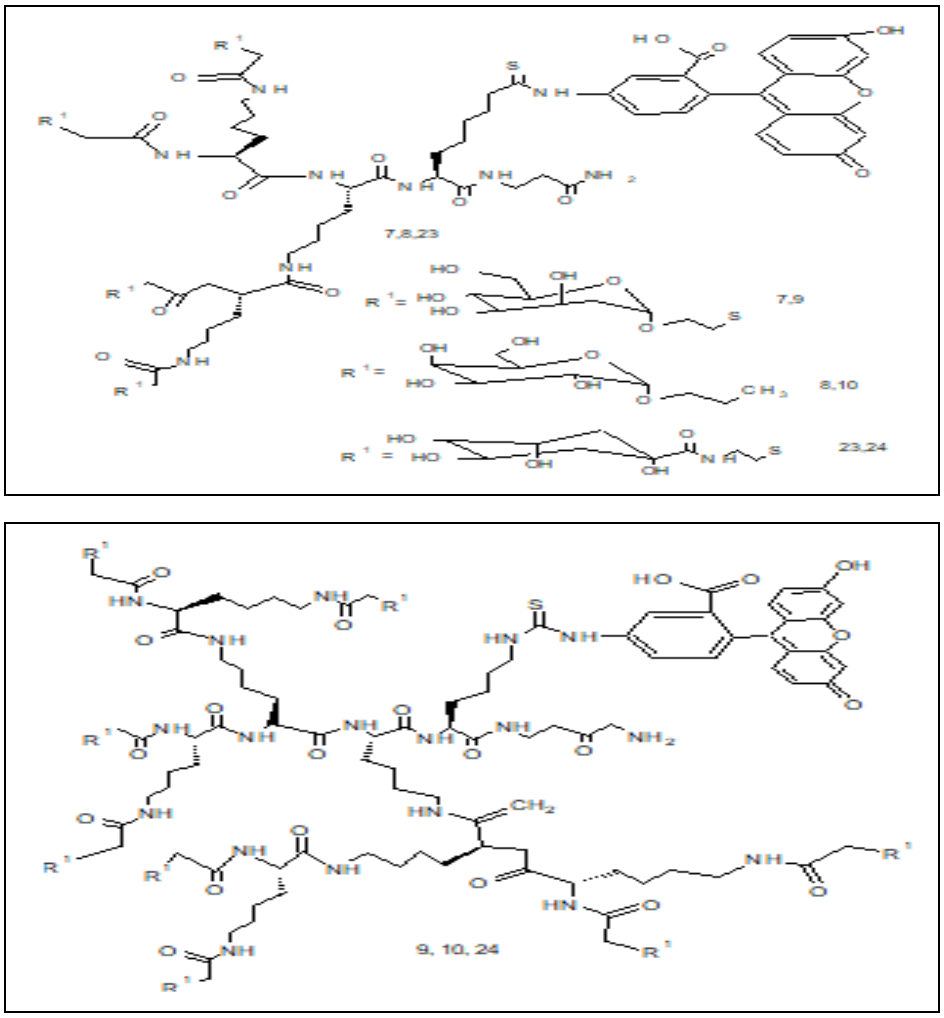


FIG. 8: BRANCHED CLUSTER GLYCOMIMETICS AND GLYCOSIDES

Hydroxyl substitution pattern which could confer additional binding capacities to mannose compared with quinic and shikimic acids.

It additional doubtless arises from (a) the distinct topologies of the ligands: The mannoside were reacted at the extremities of N-chloro acetylated-l-lysinyl trees to produce branched glycol clusters where as glycomimetics were initial coupled to a cysteine-containing tripeptide, H-l-Lys-l-Cyst (StBu)-Gly-OH, to present powerfulness inter-mediates that, in turn, were connected to the lysinyl cores to produce hyperbranched constructs, (b) the general charge of the ligands at physiological hydrogen ion concentration that is neutral or negative: the glycine rest on the tripeptide so introduces a pair of or four negative charges on the tetra- or octavalent cluster glycomimetics, severally [29].

Examples of Approved Glycomimetics Drugs: The classic samples of glycomimetics medicine area unit the infectious agent neuraminidase inhibitors Relenza and Tamiflu, that area unit used for the treatment of grippe A. each of that medicine mimic the transition state of the reaction of the terminal N-acetyl neuraminic acid by neuraminidase. Additionally, Tamiflu could be a prodrug, *i.e.*, it incorporates a further alkyl radical organic compound that will increase its property, resulting in transport and oral bioavailability. Present esterase hydrolyzes the prodrug into its active principle; several alternative glycomimetics medicine are designed to inhibit the α-glycosidase within the brush border of the tiny internal organ. Glustat, Zavesca, Glyset, and Glucobay mimic the transition state of the hydrolytic reaction and area unit used for the treatment of polygenic disorder [30].

Finally, many artificial heparins (*e.g.*, Arixtra) area unit approved. Whereas these don't seem to be strictly glycomimetics, they participate in carbohydrate-protein interactions and area unit wide used. These embody glycosidase inhibitors that forestall the digestion of carbohydrates for the bar of grippe virus infections (Relenza, Tamiflu), the treatment of the polygenic disorder (Glustat, Zavesca, Glyset, Glucobay), and sulphated glycosaminoglycans that operate as anticoagulants by binding to anti-thrombin III for the treatment of occlusion (Arixtra).

Applications of Glycomimetics:

- ✓ Endothelial dysfunctions together with tube abnormalities square measure treated with glycomimetics. Additional specifically, strategies square measure represented for victimization associate degree saccharide compound [31].
- ✓ Pyrrolidin-3-yl by-product compounds that square measure inhibitors of the beta-secretase accelerator which square measure helpful within the treatment of diseases within which the beta-secretase accelerator is concerned, like Alzheimer's [32].
- ✓ Glycyrrhizin a natural structural glycomimetics was analyzed for the power to decrease infarct size once regional heart muscle ischemia/reperfusion [33].
- ✓ Carbohydrate-containing artificial sLexmimetics, though retentive the power to supply protection against reperfusion injury, square measure pricey and troublesome to synthesize. Identification of presents Lexmimetics and also the determination of the best structural needs square measure vital for largest selectin inhibition and will assist within the style of effective, pronto synthesized selectin inhibitors [34].
- ✓ The classic samples of glycomimetics medicine square measure the microorganism neuraminidase inhibitors Relenza and Tamiflu, that square measure used for the treatment of contagious disease A [35].
- ✓ Tamiflu may be a prodrug, *i.e.*, it incorporates a further alkyl organic compound that will increase its property, resulting in transport and oral bioavailability.
- ✓ Glustat, Zavesca, Glyset, and Glucobay mimic the transition state of the hydrolytic reaction and square measure used for the treatment of polygenic disease.

Future Directions: Efforts square measure afoot in each tutorial and industrial lab to develop glycomimetics medication for numerous

glycoprotein targets, maybe the foremost heavily studied and targeted by glycomimetics antagonists square measure the selectins, that square measure a family of adhesion proteins concerned within the extravasations of cells from the blood, with a large variety of uses as well as inflammatory diseases [36, 37]. DC-SIGN may be a glycoprotein on the surface of nerve fiber cells and is employed by a spread of pathogens as portals for infection. Examples embrace HIV, TB, and dengue fever virus, hepatitis C, Ebola, Marburg, and Schistasomamansoni. Glycomimetics antagonists of DC-SIGN might have wide-ranging applications in infectious diseases [38, 39]. I-type lectins cowl an oversized family of lectins that bind sialylated carbohydrates and contain immunoglobulin-like domains. At intervals, this family, efforts to develop glycomimetics medication have targeted principally on Siglec-4 [myelin-associated compound protein (MAG)]. Glycomimetics antagonists of magazine promote redness outgrowth and have potential therapeutic applications in neuronic repair and funiculus injury. Finally, microorganism lectins also are promising targets for therapeutic interventions. PA-IL and PA-IIL square measure virulence factors of *Pseudomonas aeruginosa* and glycomimetics inhibitors of those lectins are often utilized in combination with medical aid to enhance the effectivity of ordinary antibiotic treatments. FimH may be a glycoprotein to blame for the adhesion and infectivity of uropathogenic E.coli on the tract animal tissue [40-42].

CONCLUSION: Complex carbohydrates coat all cell surfaces where they are used as recognition molecules for critical functional interactions with other cells, pathogens, and biomolecules. The entire complement of these structures, known as the glycome, maybe one of the least studied and most complicated of the molecular classifications in humans. Academic consortiums worldwide have organized resources and techniques needed to elucidate the human glycome and its functions. Many exciting new targets have been uncovered, yet this represents just the tip of the iceberg of opportunities and illustrates the vast potential of new therapeutic targets that are expected to emerge from this field.

The functional carbohydrates identified in these recognition processes themselves do not make good drug candidates. Rather, their bioactive conformations in their receptor sites can be empirically determined by physicochemical methods and used for the rational design of small molecule mimics (glycomimetics) that have higher affinities and more drug-like properties of long serum half-life, metabolic stability, low toxicity, and oral bioavailability. These glycomimetics drugs are new chemical entities and provide innovative therapeutic strategies to address current unmet needs among a wide spectrum of disease applications.

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REFERENCES:

1. Vasconcelos AA and Pomin VH: Marine Carbohydrate-Based Compounds with Medicinal Properties. Mar Drugs 2018; 16(7): 233.
2. Varki A: Biological roles of glycans. Glycobiology 2017; 27(1): 3-49.
3. Stanfield ES, Wilson R, Katinger IA, Dwek H, Rudd RA and Burton PM: Dissection of human immunodeficiency virus type 1 entry with neutralizing antibodies to gp41 fusion intermediates. Journal of Virology 2010; 76: 7306-21.
4. Nechama GG: The five bacterial lectins (PA-IL, PA-IIL, RSL, RS-IIL, and CV-IIL): interactions with diverse animal cells and glycol proteins. Advances in Experimental Medicine and Biology 2011; 705: 115-11.
5. Kumar TR, Palanirajan VK and Kumar JN: Dendrimers in Oncology: An Expanding Horizon. Chem Rev 2009; 87: 109-49.
6. Kathleen CA, Garber, Kittikhun W, Erin Carlson E and Kiessling LL: A general glycomimetics strategy yields non-carbohydrate inhibitors of DC-SIGN. Chem Commun (Camb) 2010; 46(36): 6747-49.
7. Feinberg H, Castelli, R Drickamer K, Seeberger PH and Weis WI: Multiple modes of binding enhance the affinity of DC-SIGN for high mannose N-linked glycans found on viral glycoproteins. Journal of Biology 2007; 282: 4202-09.
8. Shirley N, Masand, Isaac J, Perron, Schachner M, David I and Shreiber: Neural cell type specific responses to glycomimetics functionalized collagen. Biomaterial 2012; 3(33): 790-97.
9. Extended Neck Regions Stabilize Tetramers of the Receptors DC-SIGN and DC-SIGNR. The Journal of Biological Chemistry 2005; 280: 1327-35.
10. Kiessling LL and Splain RA: Chemical approaches to Glycobiology. Rev Biochem 2010; 79: 619-53.
11. Courtney AH, Puffer EB, Pontrello JK, Yang ZQ and Kiessling LL: Glycopolymer probes of signal transduction. Chem Soc Review 2009; 106: 2500-05.

12. Baessler KA, Lee Y and Sampson NS: Beta1 integrin is an adhesion protein for sperm binding to eggs. ACS Chem. Biol 2009; 4: 357-66.
13. Borrok MJ, Kolonko EM and Kiessling LL: Synthesis of fluorogenic polymers for visualizing cellular internalization. ACS Chem Biol 2008; 3: 101-09.
14. Cairo CW, Gestwicki JE, Kanai M and Kiessling LL: Control of multivalent interactions by binding epitope density. Am Chem Soc 2002; 124: 1615-19.
15. Rawat M, Gama CI, Matson JB and Hsieh-Wilson LC: Glycoglycan Mimic by Synthetic Polymers. J Am Chem Soc 2008; 130: 2959-61.
16. Gestwicki JE, Kanai M and Kiessling LL: Multivalent interactions by binding epitope density. J Am Chem Soc 2002; 124: 1615-19.
17. Pontrello JK, Allen MJ, Underbakke ES, Laura L and Kiessling LL: Solid-phase synthesis of polymers using the ring-opening metathesis polymerization. J Am Chem Soc 2005; 127(42): 14536-37.
18. Grim JC, Garber KC and Kiessling LL: Glycomimetics building blocks: a divergent synthesis of epimers of shikimic acid. Org Lett 2011; 13: 3790-93.
19. Taira M, Takasu N, Komiya I, Taira T and Tanaka H: Voglibose administration before the evening meal improves nocturnal hypoglycemia in insulin-dependent diabetic patients with intensive insulin therapy. Metabolism 2000; 49(4): 440-43.
20. Tori M and Mizutani R: Construction of Eight-Membered carbocycles with trisubstituted double bonds using the ring closing metathesis reaction. Molecules 2000; 15(6): 4242-60.
21. Allavena P, Chieppa M, Monti P and Piemonti L: From pattern recognition receptor to regulator of homeostasis: the double-faced macrophage mannose receptor. Immunology 2004; 24(3): 01-14.
22. Streng-Ouwehand I, Unger WWJ and Kooyk YV: C-type lectin receptors for tumor eradication: future directions. Cancers 2011; 3: 3169-88.
23. Tan MCAA, Mommaas AM, Drijfhout JW, Jordens R, Onderwater JJM and Verwoerd D: Eur J Immunol 1997; 27: 24-26.
24. Angyalosi G, Grandjean C, Lamirand M, Auriault C, Gras-Massac H and Melnykc O: Synthesis and mannose receptor-mediated uptake of clustered glycomimetics by human dendritic cells: Effect of Charge Bioorg Med Chem 2002; 12: 2723-27.
25. Ng KKS, Kolatkar AR, Park-Snyder S, Feinberg H, Clark DA, Drickamer K and I. Weis WI: Orientation of Bound Ligands in Mannose-binding Proteins implications for multivalent ligand recognition. The Journal of Biological Chemistry 2002; 277: 16088-95.
26. Grandjean C, Rommens C, Gras-Masse H and Melnyk O: Synthesis and mannose receptor-Mediated uptake of clustered glycomimetics by human dendritic cells: effect of charge. J Chem Soc Perkin Trans 1999; 2967.
27. Tam JP and Proc Natl: For use of branched oligo-lysines and application in the carbohydrate field. Acad Sci U.S.A 1988; 85: 5409.
28. Appelhans D, Klajnert-Maculewicz B, Janaszewska A, Lazniewska J and Voit B: Dendritic glycopolymers based on dendritic polyamine scaffolds: view on their synthetic approaches, characteristics and potential for biomedical applications. Chem. Soc Rev 2015; 44: 3968-96.
29. Grandjean C, Angyalosi G, Loing E, Adriaenssens E, Melnyk O and Pancre V: Functional hyper branched polymers for drug and gene delivery. Chem Bio Chem 2001; 2: 747-51.
30. Espuelas S, Haller P, Schuber F and Frisch B: Synthesis of an amphiphilic tetra antennary mannosyl conjugate and incorporation into liposome carriers. Bioorganic and Medicinal chemistry letters 2003; 13(15): 2557-60.
31. Fischer HO and Berdtsch L: (−)-Quinic acid: configurationally (stereo chemical) descriptors. Chem Ges 1921; 54: 775-68.
32. Kim CU, Lew W, Williams MA, Liu H, Zhang L and Swaminathan S: Influenza neuraminidase inhibitors possessing a novel hydrophobic interaction in the enzyme active site: design, synthesis, and structural analysis of carbocyclic sialic acid analogues with potent anti-influenza activity. J Am Chem Soc 1997; 119: 681-90.
33. Methods of use of glycomimetics with replacements for hexoses and n-acetyl hexosamines. CA02677747-2009.
34. Pyrrolidin-3-yl compounds useful as beta-secretes inhibitors for the treatment of Alzheimer's disease. WO/2006/002004.
35. Parisella ML, Angelone T, Gattuso A, Cerra MC and Pellegrino DP: Glycyrrhizin and glycyrrhetinic acid directly modulate rat cardiac performance. The Journal of Nutritional Biology 2012; 23(1): 69-75.
36. Trincone A, Perugino G, Rossi M and Moracci M: A novel thermophilic Glycosynthase that affects branching glycosylation. Bioorganic and Medicinal Chemistry Letters 2002; 10(4): 365-68.
37. Allen UD, Aoki FY and Stiver HG: The use of antiviral drugs for influenza: recommended guidelines for practitioners. Canadian Journal of Infectious Diseases and Medical Microbiology 2006; 5(17): 273-84.
38. Timpano G, Tabarani G, Anderluh M, Invernizzi D, Vasile F and Potenza D: Synthesis of novel DC-SIGN ligands with an alpha-fucosylamide anchor. Chem Biochem 2008: 1921-30.
39. Borrok MJ and Kiessling LL: Non-carbohydrate inhibitors of the lectin DC-SIGN. J Am Chem Soc 2007; 129: 12780-85.
40. Vyas AA, Blixt O, Paulson JC and Schnaar RL: Potent glycan inhibitors of myelin-associated glycoprotein enhance axon outgrowth *in-vitro*. J Biol Chem 2005; 280: 16305-10.
41. Shelke SV, Gao GP, Mesch S, Gathie H, Kelm S and Schwardt O: Synthesis of sialic acid derivatives as ligands for the myelin-associated glycoprotein (MAG). Bioorg. Med. Chem 2007; 15: 4951-65.
42. Gao G, Smiesko M, Schwardt O, Gathje H, Kelm S and Vedani A: Mimetics of the tri- and tetrasaccharide epitopes of GQ1alpha as myelin-associated glycoprotein (MAG) ligands. Bioorg Med Chem 2007; 15: 7459-69.

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