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NOMENCLATURE OF GLYCOLIPIDS

(IUPAC Recommendations 1997)

Prepared for publication by

M. ALAN CHESTER

Blood Centre, University Hospital, S-221 85 Lund, Sweden

*Members of the Commission (JCBN) at various times during the work on this document were as follows:

Chairmen: H. B. F. Dixon (UK), J. F. G. Vliegthart (The Netherlands), A. Cornish-Bowden (France), A. Kotyk (Czech Republic); **Secretaries:** A. Cornish-Bowden (France), M. A. Chester (Sweden), A. J. Barrett (UK), J. C. Rigg (The Netherlands), B. J. Whyte (Switzerland); **Members:** J. R. Bull (RSA), R. Cammack (UK), D. Coucouvanis (USA), D. Horton (USA), M. A. C. Kaplan (Brazil), P. Karlson (Germany), C. Liébecq (Belgium), K. L. Loening (USA), G. P. Moss (UK), J. Reedijk (The Netherlands), K. F. Tipton (Ireland), P. Venetianer (Hungary).

Additional contributors to the formulation of these recommendations:

Expert Panel: JCBN thanks a panel convened by C. C. Sweeley (USA), whose members were S. Basu (USA), H. Egge (Germany), G. W. Hart (USA, co-opted), S. Hakomori (USA), T. Hori (Japan: deceased 1994), P. Karlson (Germany), R. Laine (USA), R. Ledeen (USA), B. Macher (USA), L. Svennerholm (Sweden), G. Tettamanti (Italy) and H. Wiegandt (Germany) for drafting the recommendations.

Nomenclature Committee of IUBMB (NC-IUBMB) and invited observers: A. Bairoch (Switzerland), H. Berman (USA), C. R. Cantor (USA), A. D. McNaught (UK), W. Saenger (Germany), N. Sharon (Israel).

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Nomenclature of glycolipids (IUPAC Recommendations 1997)

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GL-1. GENERAL CONSIDERATIONS

Glycolipids are glycosyl derivatives of lipids such as acylglycerols, ceramides and prenols. They are collectively part of a larger family of substances known as glycoconjugates. The major types of glycoconjugates are glycoproteins, glycopeptides, peptidoglycans, proteoglycans, glycolipids and

lipopolysaccharides. The structures of glycolipids are often complex and difficult to reproduce in the text of articles and certainly cannot be referred to in oral discussions without a nomenclature that implies specific chemical structural features.

The 1976 recommendations [1] on lipid nomenclature contained a section (Lip-3) on glycolipids, with symbols and abbreviations as well as trivial names for some of the most commonly occurring glycolipids. Since then, more than 300 new glycolipids have been isolated and characterized, some having carbohydrate chains with more than twenty monosaccharide residues and others with structural features such as inositol phosphate. The nomenclature needs to be convenient and practical, as well as extensible, to accommodate newly discovered structures. It should also be consistent with the nomenclature of glycoproteins, glycopeptides and peptidoglycans [2], oligosaccharides [3], and carbohydrates in general [4].

This document supersedes the glycolipid section in the 1976 Recommendations on lipid nomenclature [1].

GL-2. GENERIC TERMS

GL-2.1. Glycolipid

The term *glycolipid* designates any compound containing one or more monosaccharide residues bound by a glycosidic linkage to a hydrophobic moiety such as an acylglycerol, a sphingoid, a ceramide (*N*-acylsphingoid) or a prenyl phosphate.

GL-2.2. Glycoglycerolipid

The term *glycoglycerolipid* is used to designate glycolipids containing one or more glycerol residues.

GL-2.3. Glycosphingolipid

The term *glycosphingolipid* designates lipids containing at least one monosaccharide residue and either a sphingoid or a ceramide. The glycosphingolipids can be subdivided as follows:

A) Neutral glycosphingolipids:

- 1) mono-, oligo-, and polyglycosylsphingoids
- 2) mono-, oligo-, and polyglycosylceramides.

B) Acidic glycosphingolipids:

- 1) sialoglycosphingolipids (gangliosides, containing one or more sialic acid residues)
- 2) uronoglycosphingolipids (containing one or more uronic acid residues)
- 3) sulfoglycosphingolipids (containing one or more carbohydrate-sulfate ester groups)
- 4) phosphoglycosphingolipids (containing one or more phosphate mono- or diester groups)
- 5) phosphonoglycosphingolipids (containing one or more (2-aminoethyl)hydroxyphosphoryl groups).

GL-2.4. Glycophosphatidylinositol

The term *glycophosphatidylinositol* is used to designate glycolipids which contain saccharides glycosidically linked to the inositol moiety of phosphatidylinositols (e.g. diacyl-*sn*-glycero-3-phosphoinositol), inclusive of lyso- (Lip-2.6 in [1]) species and those with various *O*-acyl-, *O*-alkyl-, *O*-alk-1-en-1-yl- (e.g. plasmanylinositols; [5]) or other substitutions on their glycerol or inositol residues.

GL-2.5. Psychosine

Psychosine was coined historically to designate a monoglycosylsphingoid (i.e. not acylated). The use of this term is not encouraged (Lip-3.4 in [1]).

GL-2.6. Other names

Other terms such as fucoglycosphingolipid, mannoglycosphingolipid, xyloglycosphingolipid, etc., may be used when it is important to highlight a certain structural feature of the glycolipid.

GL-3. PRINCIPLES OF NOMENCLATURE

GL-3.1. Number of monosaccharide residues

The number of monosaccharide residues in an oligosaccharide is indicated by suffixes such as “diosyl”, “triosyl”, “tetraosyl” etc. [1, 6]. Thus, the general name for the oligosaccharide residue of all glycosphingolipids containing ten monosaccharide residues is “glycodecaosyl”; it might be a glycodecaosylceramide or a 3-glycodecaosyl-1,2-diacyl-*sn*-glycerol. Recommendations have been made for the nomenclature of oligosaccharides [3, 4].

Note 1: “diosyl” not “biosyl” is the correct suffix.

Note 2: The “a” in “tetraosyl”, etc, is not elided in order to differentiate a tetrasaccharide residue (tetraosyl) from a four carbon sugar (tetrose), etc. The “a” in “triosyl” is added for a similar reason.

GL-3.2. Naming of monosaccharide residues

Monosaccharide residues are named and abbreviated (Table 1) according to the proposed nomenclature recommendations for carbohydrates [4] (see also the nomenclature of glycoproteins [2]). The D and L configurational symbols are generally omitted; all monosaccharides are D with the exception of fucose and rhamnose which are L unless otherwise specified.

Table 1 Recommended abbreviations for some monosaccharides, derivatives and related compounds

Name	Symbol
<i>N</i> -acetylgalactosamine	GalNAc
<i>N</i> -acetylglucosamine	GlcNAc
<i>N</i> -acetylneuraminic acid*	Neu5Ac or NeuAc
5,9- <i>N,O</i> -diacetylneuraminic acid*	Neu5,9Ac ₂
fucose (6-deoxygalactose)	Fuc
galactitol	Gal-ol
galactosamine	GalN
galactopyranose 3-sulfate	Galp3S
galactose	Gal
galacturonic acid	GalA
glucitol	Glc-ol
glucosamine	GlcN
glucose	Glc
glucose 6-phosphate	Glc6P
glucuronic acid	GlcA
<i>N</i> -glycolylneuraminic acid*	Neu5Gc or NeuGc
<i>myo</i> -inositol†	Ins
mannose	Man
4- <i>O</i> -methylgalactose	Gal4Me
rhamnose	Rha
xylose	Xyl

* Acylated neuraminic acids and other derivatives of neuraminic acid may also be called sialic acids (abbreviated Sia) when the nature of the *N*-acyl substituent(s) is not relevant, or is unknown [7].

† *myo*-Inositol with the numbering of the 1D configuration [8].

GL-3.3. Use of symbols for defining oligosaccharide structures

Using the condensed system of carbohydrate nomenclature [Ref. 2, section 3.7; Ref. 4, 2-Carb-38.5], positions of glycosidic linkages and anomeric configurations are expressed in parentheses between the monosaccharide residues that are thus linked. This principle should be adhered to in full names as well as the abbreviated structures. A "short form" for representing sequences more briefly can be used for specifying large structures. Positions of glycosidic linkages are still given, but the number of the anomeric carbon is omitted, since this is invariable for each monosaccharide, i.e. C-1 for Glc, etc.; C-2 for Neu5Ac, etc.

Example:

α -D-Galp-(10 \rightarrow 3)- α -D-Galp- (extended form)
 or Gal(α 1-3)Gal(α - (condensed form)
 or Gal α 3Gal α - or Gal α -3Gal α - (short form).

GL-3.4. Ring size and conformation

Ring size and conformation should be designated only when firmly established from NMR or other experimental data. Previously published recommendations on the specification of conformation should be consulted [9, 10].

Example:

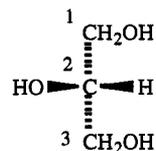
α -D-galactopyranosyl-⁴C₁-(1 \rightarrow 3)- α -D-galactopyranosyl-⁴C₁-
 or Galp⁴C₁ α 3Galp⁴C₁ α -.

Subsequently, examples will usually be in the more traditional form with parentheses and both anomeric locants, as for example Gal(β 1-4)Glc-, but it is understood that the short form (i.e. Gal β 4Glc-) is also acceptable.

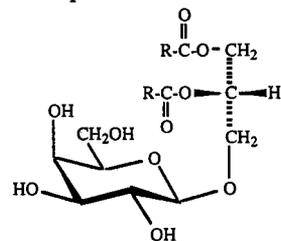
GL-4. CLASSIFICATION OF GLYCOLIPIDS BASED ON THEIR LIPID MOIETIES

GL-4.1. Glycoglycerolipids

Esters, ethers and glucose derivatives of glycerol are designated by a prefix, denoting the substituent, preceded by a locant. As previously discussed in detail [1], the carbon atoms of glycerol are numbered stereospecifically, with carbon atom 1 at the top of the formula shown below. To differentiate this numbering system from others that have been used, the glycerol is always accompanied by the prefix *sn* (for stereospecifically numbered, Lip-1.13 in [1]) in systematic and abbreviated names.

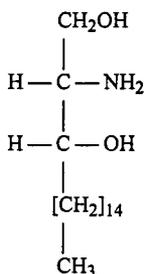


Example:

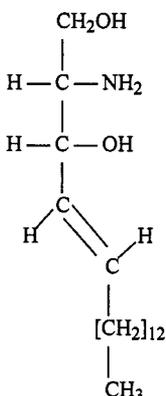


1,2-di-*O*-acyl-3-*O*- β -D-galactosyl-*sn*-glycerol

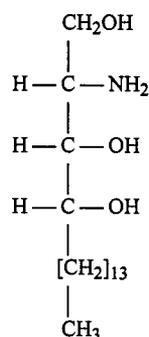
originally called phytosphingosine. According to the nomenclature adopted in 1976 [1], it should be called (2*S*,3*S*,4*R*)-2-aminooctadecane-1,3,4-triol. A trivial (but incorrect) name is (*R*)-4-hydroxysphinganine (III).



I
sphinganine



II
(*E*)-sphing-4-enine
(sphingosine)



III
(*R*)-4-hydroxysphinganine
(phytosphingosine)

4.3.3. Ceramides are *N*-acylated sphingoids. The fatty acids of naturally occurring ceramides range in chain length from about C₁₆ to about C₂₆ and may contain one or more double bonds and/or hydroxy substituents at C-2. The complete chemical name for a specific ceramide includes the sphingoid and fatty acyl substituents. For example, a ceramide containing 2-hydroxyoctadecanoic acid and sphing-4-enine should be called (*E*)-*N*-(2-hydroxyoctadecanoyl)sphing-4-enine.

GL-5. NEUTRAL GLYCOSPHINGOLIPIDS

GL-5.1. Monoglycosylceramides

The trivial name "cerebroside" was historically used for the substance from brain, β-galactosyl(1↔1)ceramide, and was later modified to include β-galactosyl(1↔1)ceramide from the spleen of a patient with Gaucher's disease. It has become a general term for these two kinds of monoglycosylceramides. However, since other monosaccharides are found in this class, the more structurally explicit terms such as glucosylceramide (GlcCer or better, Glcβ1Cer), galactosylceramide (GalCer), xylosylceramide (XylCer), etc. should be used.

GL-5.2. Diosylceramides

Diosylceramides may be named systematically, e.g. β-D-galactosyl-(1→4)-β-D-glucosyl-(1↔1)-ceramide. However, it is often more convenient to use the trivial name of the disaccharide and call the structure given above lactosylceramide (LacCer).

GL-5.3. Neutral glycosphingolipids with oligosaccharide chains

5.3.1. Systematic names for glycosphingolipids with larger oligosaccharide chains become rather cumbersome. It is therefore recommended to use semi-systematic names in which trivial names for "root" structures are used as a prefix. The recommended root names and structures are given in Table 2.

The name of a given glycosphingolipid is then composed of (root name)(root size)osylceramide. Thus, lactotetraosylceramide designates the second structure listed in Table 2 linked to a ceramide. When referring to particular glucose residues Roman numerals are used (Lip-3.9 in [1]), counting from the ceramide (see Table 2).

Table 2. Root names and structures

Root	Symbol	Root structure
		IV III II I
ganglio	Gg	Gal β 3GalNAc β 4Gal β 4Glc-
lacto*	Lc	Gal β 3GlcNAc β 3Gal β 4Glc-
neolacto†	nLc	Gal β 4GlcNAc β 3Gal β 4Glc-
globo	Gb	GalNAc β 3Gal α 4Gal β 4Glc-
isoglobot†	iGb	GalNAc β 3Gal α 3Gal β 4Glc-
mollu	Mu	GlcNAc β 2Man α 3Man β 4Glc-
arthro	At	GalNAc β 4GlcNAc β 3Man β 4Glc-

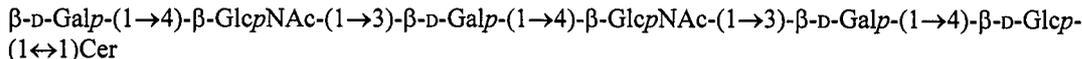
* Lacto as used here should not be confused with lactose.

† Note: The prefix "iso" is used here to denote a (1 \rightarrow 3) vs. (1 \rightarrow 4) difference in the linkage position between the monosaccharide residues III and II, while the term "neo" denotes such a difference [(1 \rightarrow 4) vs. (1 \rightarrow 3)] between residues IV and III. This scheme should be used also in other cases where such positional isomers occur, and only in such cases.

The use of the prefix "nor" for unbranched oligosaccharide chains should be abandoned since this prefix has a well-defined meaning ("one carbon atom less") in organic chemistry nomenclature.

5.3.2. The root name applies also to structures that are shorter than the root given in Table 2. Thus, gangliotriosylceramide is the name for the structure GalNAc β 4Gal β 4GlcCer, where the fourth, terminal residue is missing. The trisaccharides obtained from the lacto and neolacto series are identical and in this case the former (shorter) name should be used.

5.3.3. In the lacto series, the residues III and IV can form a repeating unit. Thus, names like neolacto-hexaosylceramide (not recommended) have been used, even though the chemical nature of the two glucose residues at the non-reducing end are not explicit in the name.



or Gal β 4GlcNAc β 3Gal β 4GlcNAc β 3Gal β 4GlcCer⁻

or Gal β -4GlcNAc β -3Gal β -4GlcNAc β -3Gal β -4GlcCer.

The correct name is β -(*N*-acetylglucosaminyl)-(1 \rightarrow 3)-neolactotetraosylceramide, where *N*-acetylglucosaminyl is β -D-Galp-(1 \rightarrow 4)-D-GlcNAc-

5.3.4. Substances containing glucose residues that are not part of a root structure should be named by referral to the root oligosaccharide and locating the additional substituents by a Roman numeral designating the position of the substituent in the root oligosaccharide (counting from the ceramide end) to which the substituent is attached, with an arabic numeral superscript indicating the position on that residue which is substituted. The anomeric configuration should also be specified.

Examples:

(i) III²- α -fucosylglobotriosylceramide

or Fuca²Gal α 4Gal β 4GlcCer

or III²- α -Fuc-Gb₃Cer

(ii) II²- β -xylosylmollutetraosylceramide

or GlcNAc β 2Man α 3(Xyl β 2)Man β 4GlcCer

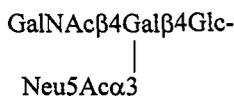
or II²- β -Xyl-Mu₄Cer

5.3.5. Branched structures should be designated in a systematic manner, locating substituents in correlation with the Haworth structure of the multiply substituted monosaccharide. This principle should be applied in full structures as well as linear formulations, wherein substituents are in one or more sets of square brackets. Such names and abbreviations should refer to the substituent on the highest carbon

number of the branched monosaccharide first, and proceed toward the substituent on the lowest carbon number. This recommendation is consistent with the nomenclature of glycoproteins, glycopeptides and peptidoglycans [2] although not explicitly stated therein.

Note: When root names (see GL-5.3.1) are used, the branches should be treated as side chains and named accordingly even when linked to a carbon atom with a higher number than the member of the root oligosaccharide. In oligosaccharide nomenclature [4] the longest chain is the parent structure. If two chains are of equal length the one with lower locants at the branch points is preferred, although some oligosaccharides are traditionally depicted otherwise - frequently NeuAc and Fuc derivatives.

Example:



or GalNAc β 4(Neu5Ac α 3)Gal β 4Glc- Otherwise in [4]: Neu5Ac α 3(GalNAc β 4)Gal β 4Glc-

or II³- α -Neu5Ac-Gg3-

GL-6. ACIDIC GLYCOSPHINGOLIPIDS

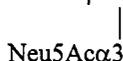
GL-6.1. Gangliosides

Gangliosides are sialoglycosphingolipids. They are named as *N*-acetyl- or *N*-glycoloyl-neuraminosyl derivatives of the corresponding neutral glycosphingolipid, using the nomenclature given in GL-5.3. The position of the sialic acid residue(s) is indicated in the same way as is the case of a branched structure.

Example:



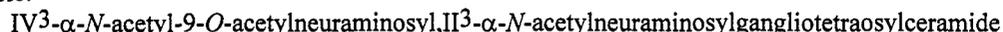
or Neu5Gc α 3Gal β 3GalNAc β 4Gal β 4GlcCer



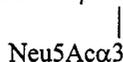
or IV³- α -Neu5Gc,II³- α -Neu5Ac-Gg4Cer.

Gangliosides containing neuraminic acid residues (with *O*-acyl or other substituents) should be named accordingly, with the positions of the substituents given.

Example:



or Neu5,9Ac 2α 3Gal β 3GalNAc β 4Gal β 4GlcCer



or IV³- α -Neu5,9Ac 2 ,II³- α -Neu5Ac-Gg4Cer.

GL-6.2. Glycuronosphingolipids

These are best named according to the guidelines of GL-5.2 and GL-5.3. Special root names have not yet been assigned.

GL-6.3. Sulfoglycosphingolipids

These are glycosphingolipids carrying a sulfate ester group, formerly called "sulfatides". They are sometimes termed sulfatoglycosphingolipids.

Sulfoglycosphingolipids may also be named as sulfate esters (sulfates) of the neutral glycosphingolipids (see GL-5).

Example:

II³-sulfo-LacCer
or lactosylceramide II³-sulfate.

GL-6.4. Phosphoglycosphingolipids

Two types of glycosphingolipids containing phosphodiester bonds are known: (i) those containing a 2-aminoethyl phosphate residue esterified to a monosaccharide residue, and (ii) those with a phosphodiester bridge between an inositol residue and the ceramide moiety.

Those of the first type can be easily named by analogy to the sulfoglycosphingolipids.

Example:

III⁶-(2-aminoethanolphospho)arthrotriosylceramide
or 6(EtnP)-GlcNAcβ3Manβ4GlcCer
or III⁶-Etn-P-At₃Cer.

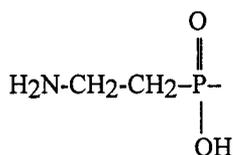
The second type can be named as inositolphosphoceramide derivatives

Example:

α-(*N*-acetylglucosaminyl)-(1→4)-α-glucuronosyl-(1→2)-inositolphosphoceramide
or Galβ4GlcNAcα4GlcAα2Ins-1-P-Cer.

GL-6.5. Phosphonoglycosphingolipids

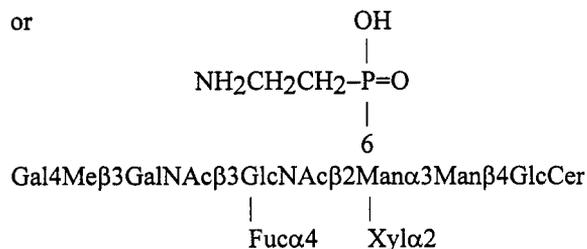
These are glycolipids esterified with an alkylphosphono acid, i.e. a compound containing a C-P bond. Their nomenclature is best derived using the prefix phosphoryl that denotes the trivalent radical O=P<. The residue



may be termed (2-aminoethyl)hydroxyphosphoryl. The location of this group is given in the same way as other ester groups.

Example:

(4-*O*-methyl-β-D-galactopyranosyl)-(1→3)-(2-acetamido-2-deoxy-β-D-galactopyranosyl)-(1→3)-[α-L-fucopyranosyl-(1→4)]-(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→2)-α-D-mannopyranosyl-(1→3)-[α-D-xylopyranosyl-(1→2)]-6-[(2-aminoethyl)hydroxyphosphoryl]-β-D-mannopyranosyl-(1→4)-β-D-glucopyranosyl-(1↔1)-ceramide
or Gal4Meβ3GalNAcβ3(Fucα4)GlcNAcβ2Manα3(Xylα2)-6-(NH₂-CH₂CH₂-P(OH)=O)Manβ4GlcCer
or



GL-7. SHORT ABBREVIATIONS

There are no easy solutions to the dilemma that has arisen from the discovery of so many (nearly 300) glycosphingolipids of diverse structures. Short abbreviations are so attractive that a logical system, with broad application to more complex compounds, is desirable.

GL-7.1. Recommended abbreviations

A system already used (GL-5.3) is based on the abbreviated root names of the oligosaccharide structures. The full root structures are tetrasaccharides, and sequential removal of terminal monosaccharide residues gives smaller, precisely defined structures. Elongation of root tetrasaccharides is on the other hand undefined and hence ambiguous. The root name may be used, followed by an arabic number indicating the total number of monosaccharide residues. A lower case letter can be added to differentiate between particular compounds.

Example:

- (i) Gal β 3GalNAc β 3Gal α 4Gal β 4GlcCer
or IV³- β -Gal-Gb₄Cer
- (ii) GalNAc α 3GalNAc β 3Gal α 4Gal β 4GlcCer
or IV³- α -GalNAc-Gb₄Cer

Either of these compounds could, after definition, be referred to as Gb₅Cer. In the presence of both structures the abbreviations Gb_{5a} and Gb_{5b} may be defined and used. It is recommended that the use of "Ose", as in GbOse₄Cer, be discontinued.

Since this short form sometimes leads to ambiguities, the full structure should be given once in a paper or in a footnote, using the abbreviated form according to GL-5.3.

GL-7.2. The Svennerholm abbreviations for brain gangliosides

In this system, the fact that we are dealing with gangliosides is indicated by the letter G, the number of sialic acid residues is stated by M for mono-, D for di-, T for tri- and Q for tetra-sialoglycosphingolipids. A number is then assigned to the individual compound which referred initially to its migration order in a certain chromatographic system [13].

Though these designations are far from being systematic, and it is impossible to derive the structure from them, they have the advantage of being short and well understood since they have been in use for a long time. A list of these abbreviations is given in Table 3.

Since there is no clear-cut system in these abbreviations, it is not recommended to extend the list by coining new symbols of this kind. As a result, the following two cases are examples of abbreviations that should not be used.

1) A disialoganglioside, Neu5Ac α 3Gal β 3(Neu5Ac α 6)GalNAc β 4Gal- β 4GlcCer, has been abbreviated GD1 α . This practice should be discontinued. The recommended abbreviation for this compound is IV³- α -Neu5Ac,III⁶- α -Neu5Ac-Gg₄Cer.

2) The system has been extended to gangliosides of other "root" types, such as those derived from lactotetraosylceramide. An example of this kind is the widely distributed ganglioside called sialoparagloboside, Neu5Ac α 3Gal β 4GlcNAc β 3Gal β 4GlcCer, which has been at times been abbreviated LM1, but should be referred to as IV³- α -Neu5Ac-nLc₄Cer.

TABLE 3. Some abbreviations using the Svennerholm system

Structure	Abbreviation*
Neu5Ac α 3Gal β 4GlcCer	GM3
GalNAc β 4(Neu5Ac α 3)Gal β 4GlcCer	GM2
Gal β 3GalNAc β 4(Neu5Ac α 3)Gal β 4GlcCer	GM1a
Neu5Ac α 3Gal β 3GalNAc β 4Gal β 4GlcCer	GM1b
Neu5Ac α 8Neu5Ac α 3Gal β 4GlcCer	GD3
GalNAc β 4(Neu5Ac α 8Neu5Ac α 3)Gal β 4GlcCer	GD2
Neu5Ac α 3Gal β 3GalNAc β 4(Neu5Ac α 3)Gal β 4GlcCer	GD1a
Gal β 3GalNAc β 4(Neu5Ac α 8Neu5Ac α 3)Gal β 4GlcCer	GD1b
Neu5Ac α 8Neu5Ac α 3Gal β 3GalNAc β 4(Neu5Ac α 3)Gal β 4GlcCer	GT1a
Neu5Ac α 3Gal β 3GalNAc β 4(Neu5Ac α 8Neu5Ac α 3)Gal β 4GlcCer	GT1b
Gal β 3GalNAc β 4(Neu5Ac α 8Neu5Ac α 8Neu5Ac α 3)Gal β 4GlcCer	GT1c
Neu5Ac α 8Neu5Ac α 3Gal β 3GalNAc β 4(Neu5Ac α 8Neu5Ac α 3)Gal β 4GlcCer	GQ1b

* Previously written using subscripts, e.g. G_{M3}, etc.

Attempts to abbreviate more complex glycosphingolipids derived from these examples have resulted in other illogical abbreviations, such as Fuc-3'-LM1 for Neu5Ac α 3Gal β 4-(Fuc α 3)GlcNAc β 3Gal β 4GlcCer (IV³- α -Neu5Ac,III³- α -Fuc-nLc₄Cer).

More information on the structures of various glycolipids and the biological material from which they were obtained may be found in several reviews [14-16].

GL-8. REFERENCES

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