

Suggestions on the Nomenclature of Sialic Acids*

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As there is still confusion about nomenclature and especially abbreviations of sialic acids, the following comments appear to be justified.

"Sialic acid" comprises all natural or synthetic derivatives of 5-amino-3,5-dideoxy-D-glycero-D-galacto-nonulosonic acid (Fig. 1), called neuraminic acid. This D-sugar is unstable in this form, due to a reaction between the C-2 keto function and the C-5 amino group. Thus, only N-acetylated derivatives occur in Nature, the most common being the N-acetylated compound 5-acetamido-3,5-dideoxy-D-glycero-D-galacto-nonulosonic acid. In solution, this monosaccharide adopts a 2C_5 -conformation with more than 90% β -anomeric configuration as established by 1H -NMR experiments ([1], Fig. 2). As all other derivatives of neuraminic acid have the same conformation, free sialic acids are generally β -anomers. Glycosidically-linked sialic acids, however, have the α -configuration, except the CMP-glycoside which is a β -anomer [2]. As this anomeric configuration is strictly followed, for simplicity α or β need not be added to abbreviations, except for synthetic derivatives with a different configuration.

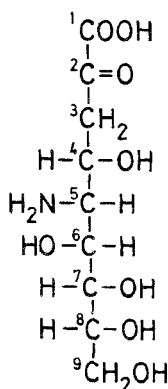


Fig. 1

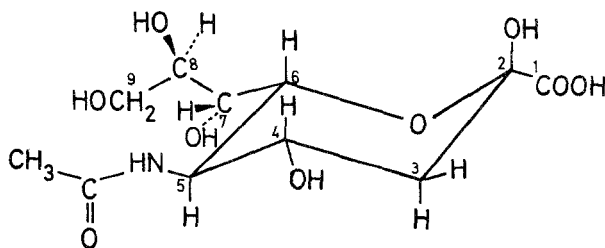


Fig. 2

* Also published in the Proceedings of the Japanese-German Symposium on Sialic Acids (1988), eds. Schauer R, Yamakawa T, Kieler Verlag Wissenschaft + Bildung, p 98–100.

Table 1. Suggested names and abbreviations for naturally occurring sialic acids [6] and two synthetic derivatives.

<i>N</i> -acetylneuraminic acid	Neu5Ac
<i>N</i> -acetyl-4- <i>O</i> -acetylneuraminic acid	Neu4,5Ac ₂
<i>N</i> -acetyl-7- <i>O</i> -acetylneuraminic acid	Neu5,7Ac ₂
<i>N</i> -acetyl-8- <i>O</i> -acetylneuraminic acid	Neu5,8Ac ₂
<i>N</i> -acetyl-9- <i>O</i> -acetylneuraminic acid	Neu5,9Ac ₂
<i>N</i> -acetyl-4,9-di- <i>O</i> -acetylneuraminic acid	Neu4,5,9Ac ₃
<i>N</i> -acetyl-7,9-di- <i>O</i> -acetylneuraminic acid	Neu5,7,9Ac ₃
<i>N</i> -acetyl-8,9-di- <i>O</i> -acetylneuraminic acid	Neu5,8,9Ac ₃
<i>N</i> -acetyl-7,8,9-tri- <i>O</i> -acetylneuraminic acid	Neu5,7,8,9Ac ₄
<i>N</i> -acetyl-9- <i>O</i> -lactoylneuraminic acid	Neu5Ac9Lt
<i>N</i> -acetyl-4- <i>O</i> -acetyl-9- <i>O</i> -lactoylneuraminic acid	Neu4,5Ac ₂ 9Lt
<i>N</i> -acetyl-8- <i>O</i> -methylneuraminic acid	Neu5Ac8Me
<i>N</i> -acetylneuraminic acid 9-phosphate	Neu5Ac9P
<i>N</i> -acetylneuraminic acid 8-sulfate	Neu5Ac8S
2-deoxy-2,3-didehydro- <i>N</i> -acetylneuraminic acid	Neu5Ac2en
2-deoxy-2,3-didehydro- <i>N</i> -acetyl-9- <i>O</i> -acetylneuraminic acid	Neu5,9Ac ₂ 2en
2-deoxy-2,3-didehydro- <i>N</i> -acetyl-9- <i>O</i> -lactoylneuraminic acid	Neu5Ac2en9Lt
<i>N</i> -glycolylneuraminic acid	Neu5Gc
<i>N</i> -glycolyl-4- <i>O</i> -acetylneuraminic acid	Neu4Ac5Gc
<i>N</i> -glycolyl-7- <i>O</i> -acetylneuraminic acid	Neu7Ac5Gc
<i>N</i> -glycolyl-9- <i>O</i> -acetylneuraminic acid	Neu9Ac5Gc
<i>N</i> -glycolyl-7,9-di- <i>O</i> -acetylneuraminic acid	Neu7,9Ac ₂ 5Gc
<i>N</i> -glycolyl-8,9-di- <i>O</i> -acetylneuraminic acid	Neu8,9Ac ₂ 5Gc
<i>N</i> -glycolyl-7,8,9-tri- <i>O</i> -acetylneuraminic acid	Neu7,8,9Ac ₃ 5Gc
<i>N</i> -(<i>O</i> -acetyl)glycolylneuraminic acid	Neu5GcAc
<i>N</i> -glycolyl-9- <i>O</i> -lactoylneuraminic acid	Neu5Gc9Lt
<i>N</i> -glycolyl-8- <i>O</i> -methylneuraminic acid	Neu5Gc8Me
<i>N</i> -glycolylneuraminic acid 8-sulfate	Neu5Gc8S
2-deoxy-2,3-didehydro- <i>N</i> -glycolylneuraminic acid	Neu2en5Gc
2-deoxy-2,3-didehydro- <i>N</i> -glycolyl-9- <i>O</i> -acetylneuraminic acid	Neu9Ac2en5Gc
2-deoxy-2,3-didehydro- <i>N</i> -glycolyl-9- <i>O</i> -lactoylneuraminic acid	Neu2en5Gc9Lt
2-deoxy-2,3-didehydro- <i>N</i> -glycolyl-8- <i>O</i> -methylneuraminic acid	Neu2en5Gc8Me
<i>N</i> -acetylneuraminic acid methyl ester	Neu5Ac1Me
<i>N</i> -acetylneuraminic acid β-methyl glycoside	Neu5Acβ2Me

Since neuraminic acid is the basic structure of sialic acids, Neu is central to all abbreviations. Acyl substituents, e.g. of the amino function at C-5, are added by the appropriate term, preceded by the number of the C-atom of Neu at which substitution took place, i.e. Neu5Ac and Neu5Gc for *N*-acetylneuraminic acid and *N*-glycolylneuraminic acid.

This general rule is followed for other substitutions at different functional positions of neuraminic acid with accepted abbreviations e.g. Me, methyl; Lt, lactoyl; P, phosphate; and S, sulfate. The substituents are listed in alphabetical order. Thus, the two most common *O*-acetylated sialic acids, *N*-acetyl-9-*O*-acetylneuraminic acid and *N*-glycolyl-9-*O*-acetylneuraminic acid, are Neu5,9Ac₂ and Neu9Ac5Gc, respectively. This system of nomenclature and abbreviations was agreed on at the Fifth International Symposium on Glycoconjugates in 1979 (Kiel, W. Germany). It has, however, only been used by a few groups.

This system can be extended to all sialic acids. The unsaturated compound 2-deoxy-2,3-didehydro-*N*-acetylneuraminic acid is abbreviated Neu5Ac2en, according to the rules of carbohydrate nomenclature. For a newly discovered derivative of Neu5Gc *O*-acetylated at the glycoloyl OH-function we propose Neu5GcAc as abbreviation and *N*-(*O*-acetyl) glycoloylneuraminic acid as the full name [3]. Finally, for synthetic compounds derived from sialic acids by epimerisation at one or more asymmetric C-atoms, we propose using the number(s) of the epimerized C-atom(s) followed by "epi" as prefix of the parent sialic acid, although these derivatives no longer have the *D-glycero-D-galacto* configuration and are thus not true derivatives of neuraminic acid [4]. For example, *N*-acetylneuraminic acid, epimerized at C-4 and C-7 and thus having the *D-glycero-L-allo* configuration should be called 4,7-di-epi-*N*-acetylneuraminic acid, 4,7-epi₂-Neu5Ac. Similarly, newly introduced deoxy functions of sialic acids are named by the number of the appropriate C-atom followed by "d", e.g. 9-d-Neu5Ac for 9-deoxy-*N*-acetylneuraminic acid [4]. The methyl ester and the β -methyl glycoside of Neu5Ac, which are well established synthetic derivatives, should be abbreviated as Neu5Ac1Me and Neu5Ac β 2Me, respectively.

All these sugars and those listed in Table 1 are sialic acids. This general name should always be used if the exact nature is not known or not of importance. Therefore, the enzyme releasing sialic acids from their α -ketosidic linkages should be called sialidase (EC 3.2.1.18), as it acts not only on Neu5Ac. The term neuraminidase implies enzymatic hydrolysis of neuraminic acid, Neu, which is not a natural substance and no substrate for sialidase, and should therefore be avoided. Similarly, other enzymes of sialic acid metabolism [5] should be named accordingly.

References

- 1 Haverkamp J, van Halbeek H, Dorland L, Vliegthart JFG, Pfeil R, Schauer R (1982) Eur J Biochem 122:305-11.
- 2 Haverkamp J, Spoormaker T, Dorland L, Vliegthart JFG, Schauer R (1979) J Am Chem Soc 101:4851-53.
- 3 Reuter G, Kluge A, Jibril S, Kelm S, Schauer R (1987) in Carbohydrates, eds. Lichtenhaler FW, Neff KH, Ges Dt Chem, Frankfurt, B-15.
- 4 Schauer R, Stoll S, Zbiral E, Schreiner E, Brandstetter HH, Vasella A, Baumberger F (1987) Glycoconjugate J 4:361-69.
- 5 Schauer R (1987) Methods Enzymol 138:611-26.
- 6 Schauer R (1982) Adv Carbohydr Chem Biochem 40:131-234.