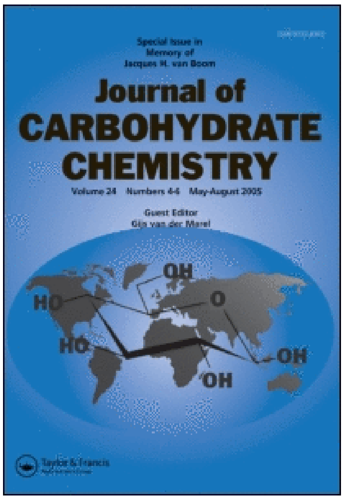

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SYNTHETIC STUDIES ON SIALOGLYCOCONJUGATES 31: SYNTHESIS OF GANGLIOSIDE GM3 ANALOGS CONTAINING THE CHEMICALLY MODIFIED SIALIC ACIDS

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ABSTRACT

Ganglioside GM3 analogs, containing 4-*O*- and 9-*O*-methyl-, and 8-epi-*N*-acetylneuraminic acids in the place of *N*-acetylneuraminic acid (Neu5Ac) have been synthesized. The methyl α-2-thioglycosides **10**, **11**, and **12** of 4-*O*-methyl, 9-*O*-methyl, and 8-*epi*-Neu5Ac derivatives were synthesized from methyl (methyl 5-acetamido-3,5-dideoxy-2-thio-D-*glycero*-α-D-*galacto*-2-nonulopyranosid)onate as the glycosyl donors. Glycosylation of 2-(trimethylsilyl)ethyl *O*-(6-*O*-benzoyl-β-D-galactopyranosyl)-(1→4)-2,6-di-*O*-benzoyl-β-D-glucopyranoside (**13**) with compounds **10**, **11**, and **12** using dimethyl(methylthio)sulfonium triflate (DMTST) as a glycosyl promoter, gave the corresponding 2-(trimethylsilyl)ethyl sialyl α(2→3')-β-lactosides **14**, **18**, and **22**, respectively, which were converted, *via* *O*-acetylation, selective removal of the 2-(trimethylsilyl)ethyl group, and subsequent imidate formation, into the sialyl α(2→3')-lactose trichloroacetimidates **17**, **21**, and **25**. Glycosylation of (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol (**26**) with compounds **17**, **21**, and **25** in the presence of boron trifluoride etherate afforded the corresponding β-glycosides **27**, **30**, and **33** in good yields, which were transformed, *via* selective reduction of the azide group, coupling with octadecanoic acid, *O*-deacylation, and hydrolysis of the methyl ester group, into the end products **29**, **32**, and **35**, respectively.

INTRODUCTION

Recently, it has been widely recognized that sialoglycoconjugates the so-called gangliosides and glycoproteins, have biological roles[1-5] such as cell growth, differentiation, adhesion, oncogenesis, receptor functions for viruses and bacterial toxins, and ligand activities[6-14] for ELAM-1 and CD-62. It is also well known that the sialic acids as constituents of glycoconjugates are closely associated with the functions. In view of these facts, and in order to investigate the functions of gangliosides at the molecular level, not only the synthesis of a variety of gangliosides, but also of the analogs containing various types of sialic acids and lipophilic part is of critical importance. As a part of our continuing efforts[15] on the synthesis and structure-function relationship of gangliosides, we describe here the synthesis of ganglioside GM3 analogs containing the 4-*O*-methyl-, 9-*O*-methyl-, and 8-epi-*N*-acetylneuraminic acids, in order to clarify the structural requirement of the sialic acid moiety for the functions of GM3.

RESULTS AND DISCUSSION

For the synthesis of the desired ganglioside GM3 analogs containing the modified Neu5Ac, the methyl α-2-thioglycosides **10**~**12** of sialic acids as the glycosyl donors and 2-(trimethylsilyl)ethyl *O*-(6-*O*-benzoyl-β-D-galactopyranosyl)-(1→4)-2,6-di-*O*-benzoyl-β-D-glucopyranoside[16](**13**) as a suitably protected glycosyl acceptor have been employed. The acceptor **13** can be coupled with the donors using dimethyl(methylthio)-sulfonium triflate[17] (DMTST) as a glycosyl promoter in acetonitrile under kinetically controlled conditions by us.[16] According to our method,[16,18] the oligosaccharides thus obtained can be converted, by introduction of a ceramide moiety, into the end products.

Treatment of methyl (methyl 5-acetamido-3,5-dideoxy-8,9-*O*-isopropylidene-2-thio-D-*glycero*-α-D-*galacto*-2-nonulopyranosid)onate[19] (**1**) with methyl iodide in the presence of AgO exclusively gave the 4-*O*-methyl derivative **2** in 77% yield. Removal of the isopropylidene group from **2** with 80% aqueous acetic acid and subsequent acetylation gave methyl (methyl 5-acetamido-7,8,9-tri-*O*-acetyl-3,5-dideoxy-4-*O*-methyl-2-thio-D-*glycero*-α-D-*galacto*-2-nonulopyranosid)onate (**10**) in 91% yield. Significant signals in ^{1}H NMR spectrum of **10** were seven three-proton singlets at δ 1.96 (AcN), 2.04, 2.11, 2.14, and 2.16 (3AcO, MeS), 3.34 (MeO), 3.81 (MeOCO), H-4 (m) at δ 3.62 and H-7 (dd, $J_{6,7}$ = 1.7 Hz, $J_{7,8}$ = 8.5 Hz) at δ 5.31, indicating the structure assigned.

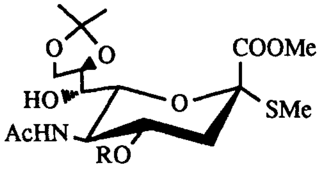
Treatment of methyl (methyl 5-acetamido-3,5-dideoxy-2-thio-D-*glycero*-α-D-*galacto*-2-nonulopyranosid)onate[20] (**3**) with *t*-butyldimethylsilyl chloride in pyridine gave the 9-*O*-*t*-butyldimethylsilyl derivative **4** in 93% yield, which was benzoylated with benzoyl chloride in pyridine at -5 °C to give the 4,8-di-*O*-benzoyl derivative **5**. Hydrolysis of the *O*-*t*-butyldimethylsilyl group in **5** with 80% aqueous acetic acid afforded **6** in 86% yield, which, on treatment with trimethyloxonium tetrafluoroborate in the presence of 2,6-di-*t*-butyl-4-methylpyridine in dichloromethane, selectively gave the

9-*O*-methyl derivative **7** in 96% yield. Acetylation of **7** gave glycosyl donor **12**. The ^{1}H NMR spectrum of **12** showed the presence of one *N*-acetyl (δ 1.76), each one *O*-acetyl and *S*-methyl (δ 2.20, 2.22), methyl ether (δ 3.33), methyl ester (δ 3.54), H-4 at δ 5.12 (ddd), H-7 at δ 5.54 (dd), and H-8 at δ 5.66 (m), and these data are consistent with the 9-*O*-methyl-sialic acid derivative **12**. When treated with methanesulfonyl chloride in pyridine, methyl (methyl 5-acetamido-4,7-di-*O*-acetyl-3,5-dideoxy-2-thio-D-*glycero*-α-D-*galacto*-2-nonulopyranosid)onate[19] (**8**) gave the 8,9-di-*O*-mesyl derivative **9** in good yield, which was converted, by treatment with cesium acetate in the presence of 18-crown-6 in *N,N*-dimethylformamide for 24 h at 120 °C, into methyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-2-thio-L-*glycero*-α-D-*galacto*-2-nonulopyranosid)-onate (**12**) in 91% yield.

The glycosylation of **13**[16] with **10** (2.0 equiv to the acceptor) in acetonitrile for 24 h at -15 °C in the presence of DMTST (4.0 equiv to **10**) and molecular sieves 3 Å, exclusively gave the α-glycoside **14** in 38% yield. Acetylation of **14** with acetic anhydride in pyridine gave the acetate **15**. The structure of **15** was unambiguously proved by 270 MHz ^{1}H NMR spectroscopy. The observed chemical shifts and coupling constants of the sialic acid unit for H-3e (δ 2.86, $J_{3a,3e}$ = 12.5 Hz, $J_{3e,4}$ = 4.0 Hz), H-7 (δ 5.45, $J_{6,7}$ = 2.6 Hz, $J_{7,8}$ = 9.1 Hz) and H-8 (δ 5.69) are characteristic of the anomeric configuration of the α-glycosidic linkage[21-24] of sialic acid analogs, and of the lactose unit for H-2' (δ 5.15, $J_{1',2'}$ = 8.1 Hz, $J_{2',3'}$ = 10.3 Hz), H-3' (δ 4.71, $J_{3',4'}$ = 3.3 Hz), and H-4' (δ 5.12, broad d) are indicating the glycosidic position to be C-3'. Other ^{1}H NMR data are given in the Experimental Section and are consistent with the structure assigned.

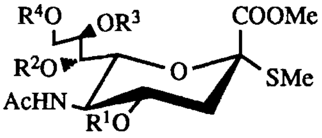
In essentially the same way, reaction of **13** with **11** or **12** yielded the corresponding sialyl α(2→3')-lactosides **18** and **22** in 50 and 55% yields, respectively. It is noteworthy that neither the unexpected β-glycoside nor position isomer was isolated in this reaction. Acetylation of **18** and **22** gave the acetates **19** and **23** in almost quantitative yields.

Selective removal[16,25] of the 2-(trimethylsilyl)ethyl group in **15**, **19**, and **23** was performed by treatment with $BF_3 \cdot OEt_2$ in dichloromethane for 4 h at 0 °C, to give the corresponding 1-hydroxyl derivatives **16**, **20**, and **24** in high yields (89~94%). Treatment[16b,26,27] of **16**, **20**, and **24** with trichloroacetonitrile in the presence of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) for 2 h at 0 °C gave the corresponding trichloroacetimidates **17**, **21**, and **25**, as the α-anomers in 81~96% yields, respectively. The glycosylation[16b,28] of (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol[29,30] (**26**) with **17**, **21**, or **25** thus obtained, in dichloromethane at 0 °C in the presence of $BF_3 \cdot OEt_2$, gave only the desired β-glycosides **27**, **30**, and **33** in good yields, respectively. A significant signal in the ^{1}H NMR spectra of **27**, **30**, or **33** was



1 R = H

2 R = Me



3 $R^1 = R^2 = R^3 = R^4 = H$

4 $R^1 = R^2 = R^3 = H, R^4 =$ TBDMS

5 $R^1 = R^3 =$ Bz, $R^2 = H, R^4 =$ TBDMS

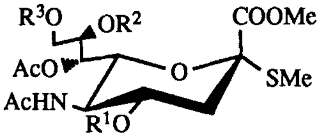
6 $R^1 = R^3 =$ Bz, $R^2 = R^4 = H$

7 $R^1 = R^3 =$ Bz, $R^2 = H, R^4 =$ Me

8 $R^1 = R^2 =$ Ac, $R^3 = R^4 = H$

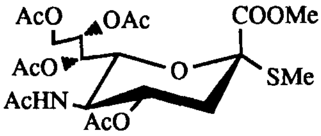
9 $R^1 = R^2 =$ Ac, $R^3 = R^4 =$ Ms

TBDMS = $Me_3C(Me_2)Si$
Bz = benzoyl
Ms = $MeSO_2$

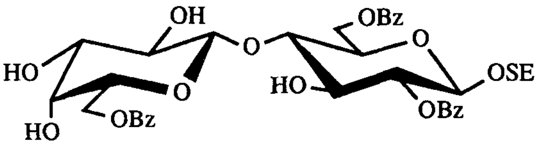


10 $R^1 =$ Me, $R^2 = R^3 =$ Ac

11 $R^1 = R^2 =$ Bz, $R^3 =$ Me

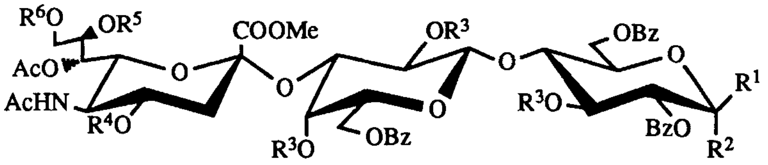


12

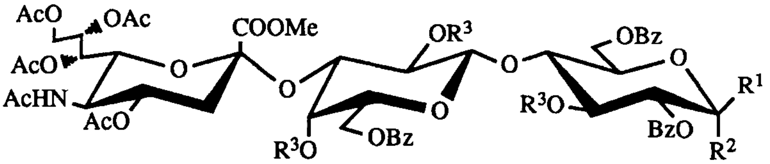


13

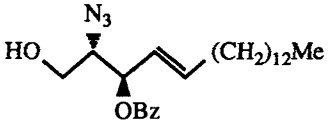
SE = 2-(trimethylsilyl)ethyl



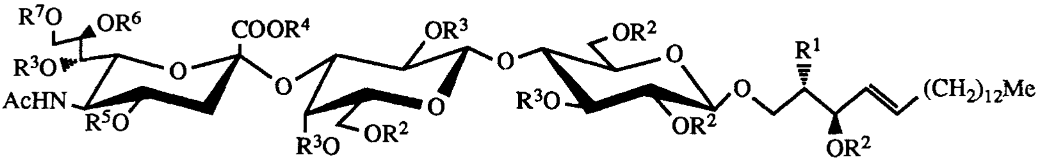
14 R^1 = OSE, R^2 = R^3 = H, R^4 = Me, R^5 = R^6 = Ac
15 R^1 = OSE, R^2 = H, R^3 = R^5 = R^6 = Ac, R^4 = Me
16 R^1, R^2 = H, OH, R^3 = R^5 = R^6 = Ac, R^4 = Me
17 R^1 = H, R^2 = OC(=NH)CCl_3, R^3 = R^5 = R^6 = Ac, R^4 = Me
18 R^1 = OSE, R^2 = R^3 = H, R^4 = R^5 = Bz, R^6 = Me
19 R^1 = OSE, R^2 = H, R^3 = Ac, R^4 = R^5 = Bz, R^6 = Me
20 R^1, R^2 = H, OH, R^3 = Ac, R^4 = R^5 = Bz, R^6 = Me
21 R^1 = H, R^2 = OC(=NH)CCl_3, R^3 = Ac, R^4 = R^5 = Bz, R^6 = Me



22 R^1 = OSE, R^2 = R^3 = H
23 R^1 = OSE, R^2 = H, R^3 = Ac
24 R^1, R^2 = H, OH, R^3 = Ac
25 R^1 = H, R^2 = OC(=NH)CCl_3, R^3 = Ac



26



27 $R^1 = N_3$, $R^2 = Bz$, $R^3 = R^6 = R^7 = Ac$, $R^4 = R^5 = Me$

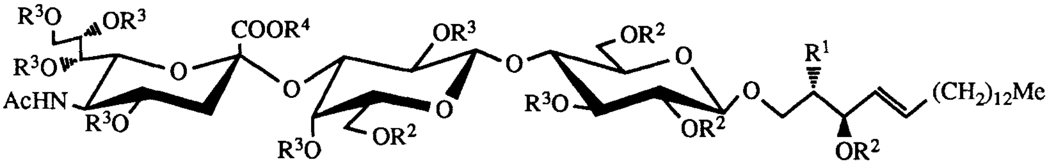
28 $R^1 = NHCO(CH_2)_{16}Me$, $R^2 = Bz$, $R^3 = R^6 = R^7 = Ac$, $R^4 = R^5 = Me$

29 $R^1 = NHCO(CH_2)_{16}Me$, $R^2 = R^3 = R^4 = R^6 = R^7 = H$, $R^5 = Me$

30 $R^1 = N_3$, $R^2 = R^5 = R^6 = Bz$, $R^3 = Ac$, $R^4 = R^7 = Me$

31 $R^1 = NHCO(CH_2)_{16}Me$, $R^2 = R^5 = R^6 = Bz$, $R^3 = Ac$, $R^4 = R^7 = Me$

32 $R^1 = NHCO(CH_2)_{16}Me$, $R^2 = R^3 = R^4 = R^5 = R^6 = H$, $R^7 = Me$



33 $R^1 = N_3$, $R^2 = Bz$, $R^3 = Ac$, $R^4 = Me$

34 $R^1 = NHCO(CH_2)_{16}Me$, $R^2 = Bz$, $R^3 = Ac$, $R^4 = Me$

35 $R^1 = NHCO(CH_2)_{16}Me$, $R^2 = R^3 = R^4 = H$

one-proton doublet at δ 4.66~4.71 ($J_{1,2}$ = 7.3~8.1 Hz, H-1 of lactose unit), indicating the newly formed glycosidic linkage to be β.

Selective reduction[31] of the azide group in **27**, **30**, and **33** with hydrogen sulfide in aqueous pyridine for 25 h at room temperature, and subsequent condensation with octadecanoic acid, using 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (WSC) in dichloromethane, gave the corresponding acylated ganglioside GM3 analogs **28**, **31**, and **34** in good yields, respectively. *O*-Deacylation of **28**, **31**, or **34** with sodium methoxide in methanol, with subsequent saponification of the methyl ester group, yielded the end products **29**, **32**, and **35** in almost quantitative yields. The ^{1}H NMR data of the products are consistent with the structures assigned.

The work described here shows the use of the methyl 2-thioglycosides of sialic acids as glycosyl donor in acetonitrile in the presence of DMTST is effective for obtaining the α-glycosides of sialic acids.

EXPERIMENTAL

General Procedures. Specific rotations were determined with a Union PM-201 polarimeter at 25 °C, and IR spectra were recorded with a Jasco A-100 spectrophotometer. ^{1}H NMR spectra were recorded with a JEOL JNM-GX 270 spectrometer. Preparative chromatography was performed on silica gel (Wako Co., 200 mesh) with the solvent systems specified. Concentrations were conducted *in vacuo.*

Methyl (Methyl 5-Acetamido-3,5-dideoxy-8,9-O-isopropylidene-4-O-methyl-2-thio-D-glycero-α-D-galacto-2-nonulopyranosid)onate (2). To a stirred solution of methyl (methyl 5-acetamido-3,5-dideoxy-8,9-*O*-isopropylidene-2-thio-D-*glycero*-α-D-*galacto*-2-nonulopyranosid)onate[19] (**1**; 1.0 g, 0.24 mmol) in MeOH (5 mL), cooled to 0 °C, were added CH_3I(360 mg, 2.53 mmol) and AgO (300 mg, 1.29 mmol), and the mixture was stirred for 6 h at room temperature. After completion of the reaction, the precipitate was filtered off, and washed with CH_2Cl_2. The combined filtrate and washings were concentrated to a syrup that was chromatographed on a column of silica gel (30 g) with 70 : 1 CH_2Cl_2-MeOH, to give compound **2** (80 mg, 77%) as an amorphous mass; $[\alpha]_D$ +19.0° (*c* 1.2, $CHCl_3$); IR (KBr) 3500-3300 (OH, NH), 1740 and 1220 (ester), 1650 and 1550 (amide), and 850 cm^{-1} (Me_2C); ^{1}H NMR ($CDCl_3$) δ 1.37 (2s, 6H, Me_2C), 1.72 (t, 1H, $J_{3a,3e} = J_{3a,4} = 12.6$ Hz, H-3a), 2.01 (s, 3H, AcN), 2.19 (s, 3H, MeS), 2.73 (dd, 1H, $J_{3e,4}= 4.4$ Hz, H-3e), 3.26 (d, 1H, $J_{5,6} = 10.6$ Hz, $J_{6,7} = 2.6$ Hz, H-6), 3.35 (s, 3H, MeO), 3.40 (m, 1H, H-4), 3.81 (s, 3H, MeOCO), 3.86 (dd, 1H, H-7), 4.08 (q, 1H, $J_{4,5} = J_{5,6} = J_{5,NH} = 10.6$ Hz, H-5), and 4.09 and 4.30 (m, 2H, H-9,9').

Anal. Calcd for $C_{17}H_{29}NO_8S$ (407.5): C, 50.11; H, 7.17; N, 3.44. Found: C, 50.15; H, 7.23; N, 3.41.

Methyl (Methyl 5-Acetamido-9-O-t-butyldimethylsilyl-3,5-dideoxy-2-thio-D-glycero-α-D-galacto-2-nonulopyranosid)onate (4). To a stirred solution of methyl (methyl 5-acetamido-3,5-dideoxy-2-thio-D-*glycero*-α-D-*galacto*-2-nonulopyranosid)onate[20] (**3**; 2.06 g, 5.83 mmol) in pyridine (40 mL), cooled to 0 °C, was added *t*-butyldimethylsilyl chloride (1.7 g, 1.13 mmol), and the mixture was stirred for 2 h at 0 °C. Methanol (1 mL) was added to the mixture and this was stirred for 1 h at room temperature, and concentrated. Column chromatography (4 : 1 AcOEt-hexane) of the residue on silica gel (100 g) gave **4** (2.54 g, 93%) as an amorphous mass; $[\alpha]_D$ +24.5° (*c* 0.8, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.82 (s, 9H, Me_3C), 1.80 (t, 1H, $J_{3a,3e} = J_{3a,4} = 13.0$ Hz, H-3a), 1.92 (s, 3H, AcN), 2.01 (s, 3H, MeS), 2.71 (dd, 1H, $J_{3e,3e} = 13.0$ Hz, $J_{3e,4}= 4.6$ Hz, H-3e), 3.22 (dd, 1H, $J_{5,6} = 10.3$ Hz, $J_{6,7} = 1.2$ Hz, H-6), and 3.75 (s, 3H, MeO).

Anal. Calcd for $C_{19}H_{37}NO_8SSi$ (467.7): C, 48.80; H, 7.98; N, 3.00. Found: C, 48.73; H, 7.80; N, 2.84.

Methyl (Methyl 5-Acetamido-4,8-di-O-benzoyl-9-O-t-butyldimethylsilyl-3,5-dideoxy-2-thio-D-glycero-α-D-galacto-2-nonulopyranosid)onate (5). To a stirred solution of **4** (100 mg, 0.21 mmol) in pyridine (1 mL)-CH_2Cl_2 (3 mL), cooled to -5 °C, was added a solution of benzoyl chloride (0.15 mL, 1.29 mmol) in CH_2Cl_2 (1 mL), and the mixture was stirred for 1.5 h at -5 °C, and then MeOH (1 mL) was added. The mixture was concentrated and extracted with CH_2Cl_2. The extract was successively washed with 2 M HCl and water, dried (Na_2SO_4), and concentrated. Column chromatography (1 : 3 AcOEt-hexane) of the residue on silica gel (30 g) gave **5** (110 mg, 76%) as an amorphous mass; $[\alpha]_D$ +12.0° (*c* 0.7, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.89 (s, 9H, Me_3C), 1.92 (s, 3H, AcN), 2.25 (s, 3H, MeS), 2.90 (dd, 1H, $J_{3a,3e}$ = 12.5 Hz, $J_{3e,4}$ = 4.6 Hz, H-3e), 3.25 (s, 3H, MeO), 3.51 (dd, 1H, $J_{5,6}$ 10.3 Hz, $J_{6,7}$ 1.0 Hz, H-6), 4.05-4.18 (m, 3H, H-7,9,9'), 4.18 (q, 1H, $J_{4,5}$ = $J_{5,6}$ = $J_{5,NH}$ = 10.3 Hz, H-5), 4.83 (d, 1H, OH-7), 5.28 (ddd, 1H, H-4), 5.46 (m, 1H, H-8), 6.29 (d, 1H, NH), and 7.47-8.13 (m, 10H, 2Ph).

Anal. Calcd for $C_{33}H_{45}NO_{10}SSi$ (675.9): C, 58.64; H, 6.71; N, 2.07. Found: C, 58.63; H, 6.79; N, 1.93.

Methyl (Methyl 5-Acetamido-4,8-di-O-benzoyl-3,5-dideoxy-2-thio-D-glycero-α-D-galacto-2-nonulopyranosid)onate (6). A solution of **5** (72 mg, 0.1 mmol) in 80% aqueous acetic acid (3 mL) was heated, with stirring, for 2 h at 40 °C, and concentrated. Column chromatography (2 : 1 $AcOEt_2$-hexane) of the residue on silica gel (20 g) gave **6** (52 mg, 85.5%) as an amorphous mass; $[\alpha]_D$ -3.1° (*c* 0.6, $CHCl_3$); ^1H NMR (1 : 1 $CDCl_3$-CD_3OD) δ 2.08 (t, 1H, $J_{3a,3e}$ = $J_{3a,4}$ = 12.5 Hz, H-3a), 1.90 (s, 3H, AcN), 2.18 (s, 3H, MeS), 2.89 (dd, 1H, $J_{3e,4}$ 4.6 Hz, H-3e), 3.32 (s, 3H, MeO), 3.55 (dd, 1H, $J_{5,6}$ = 10.4 Hz, $J_{6,7}$ = 1.0 Hz, H-6), 3.89-4.12 (m, 3H, H-7,9,9'), 4.25 (t, 1H, $J_{4,5}$ = $J_{5,6}$ = $J_{5,NH}$ = 10.4 Hz, H-5), 5.19 (ddd, 1H, H-4), 5.41 (m, 1H, $J_{7,8}$ = 9.0 Hz, H-8), and 7.32-8.10 (m, 10H, 2Ph).

Anal. Calcd for $C_{27}H_{31}NO_{10}S$ (561.1): C, 57.74; H, 5.56; N, 2.49. Found: C, 57.63; H, 5.50; N, 2.43.

Methyl (Methyl 5-Acetamido-4,8-di-O-benzoyl-9-O-methyl-2-thio-D-glycero-α-D-galacto-2-nonulopyranosid)onate (7). To a solution of **6** (1.5 g, 2.67 mmol) in CH_2Cl_2 (60 mL), cooled to 0 °C, were added, with stirring, 2.6-di-*t*-butyl-4-methylpyridine (1.5 g, 7.3 mmol) and trimethyloxonium tetrafluoroborate (1.0 g, 6.76 mmol), and the mixture was stirred for 30 min at 0 °C; the course of the reaction was monitored by TLC. After completion of the reaction, MeOH (1 mL) was added, and concentrated. Column chromatography (1 : 4 AcOEt-hexane) of the residue on silica gel

(100 g) gave **7** (1.49 g, 96%) as an amorphous mass; $[\alpha]_D$ +5.9° (*c* 1.2, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.91 (s, 3H, AcN), 2.17 (s, 3H, MeS), 2.84 (dd, 1H, $J_{3a,3e}$ = 12.6 Hz, $J_{3e,4}$ = 4.8 Hz, H-3e), 3.23, 3.34 (2s, 6H, 2MeO), 3.47 (dd, 1H, $J_{5,6}$ = 10.5 Hz, $J_{6,7}$ = 1.6 Hz, H-6), 3.81-3.91 (m, 2H, H-9,9'), 4.19 (q, 1H, $J_{4,5}$ = $J_{5,6}$ = $J_{5,NH}$ = 10.5 Hz, H-5), 4.80 (d, 1H, OH-7), 5.21 (ddd, 1H, H-4), 5.49 (m, 1H, H-8), 6.20 (d, 1H, NH), and 7.39-8.08 (m, 10H, 2Ph).

Anal. Calcd for $C_{28}H_{33}NO_{10}S$ (575.6): C, 58.42; H, 5.78; N, 2.43. Found: C, 58.30; H, 5.94; N, 2.39.

Methyl (Methyl 5-Acetamido-4,7-di-O-acetyl-3,5-dideoxy-8,9-di-O-mesyl-2-thio-D-glycero-α-D-galacto-2-nonulopyranosid)onate (9). To a solution of methyl (methyl 5-acetamido-4,7-di-*O*-acetyl-3,5-dideoxy-2-thio-D-*glycero*-α-D-*galacto*-2-nonulopyranosid)onate[19] (**8**; 6.0 g, 1.37 mmol) in pyridine (50 mL), cooled to -5 °C, was added methanesulfonyl chloride (3.7 mL), and the mixture was stirred for 6 h at 0 °C. Methanol (3 mL) was added to the mixture and concentrated to a syrup which was extracted with CH_2Cl_2. The extract was washed successively with 2 M HCl and water, dried (Na_2SO_4), and concentrated. Column chromatography (3 : 2 AcOEt-hexane) of the residue on silica gel (150 g) gave **9** (6.7 g, 83%) as an amorphous mass; $[\alpha]_D$ +31.0° (*c* 0.9, $CHCl_3$); IR (KBr) 3450 (NH), 1740 and 1220 (ester), 1660 and 1550 (amide), and 1360 and 1180 cm^{-1} (SO_2); ^1H NMR ($CDCl_3$) δ 1.88 (s, 3H, AcN), 2.03, 2.18, 2.19 (3s, 9H, 2AcO, MeS), 2.78 (dd, 1H, $J_{3a,3e}$ = 12.8 Hz, $J_{3e,4}$ = 4.8 Hz, H-3e), 3.11, 3.19 (2s, 6H, $2MeSO_2$), 3.71 (s, 3H, MeO), 3.88 (dd, 1H, $J_{5,6}$ = 10.3 Hz, $J_{6,7}$ = 2.2 Hz, H-6), 4.06 (q, 1 H, $J_{4,5}$ = $J_{5,6}$ = $J_{5,NH}$ = 10.3 Hz, H-5), 4.39, 4.80 (2dd, 2H, $J_{8,9}$ = 8.1 Hz, $J_{8,9'}$ = 2.6 Hz, $J_{9,9'}$ = 11.7 Hz, H-9,9'), 4.93 (ddd, 1H, H-4), 5.23 (ddd, 1H, $J_{7,8}$ = 5.5 Hz, H-8), 5.48 (dd, 1H, H-7), and 5.80 (d, 1H, NH).

Anal. Calcd for $C_{19}H_{31}NO_{14}S_3$ (593.4): C, 38.45; H, 5.27; N, 2.36. Found: C, 38.44; H, 5.33; N, 2.29.

Methyl (Methyl 5-Acetamido-7,8,9-tri-O-acetyl-3,5-dideoxy-4-O-methyl-2-thio-D-glycero-α-D-galacto-2-nonulopyranosid)onate (10). A solution of **2** (2.0 g, 4.9 mmol) in 80% aqueous acetic acid (80 mL) was stirred for 20 h at room temperature, and concentrated. The residue was acetylated with acetic anhydride (10 mL)-pyridine (20 mL) for 12 h at room temperature. The product was purified by chromatography on silica gel (80 g) with 2 : 3 AcOEt-hexane, to give **10** (2.2 g, 91%) as an amorphous mass; $[\alpha]_D$ +56.0° (*c* 1.5, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.67 (t, 1H, $J_{3a,3e}$ = $J_{3a,4}$ = 12.6 Hz, H-3a), 1.96 (s, 3 H, AcN), 2.04, 2.11, 2.14, 2.16 (4s, 12H, 3AcO, MeS), 2.88 (dd, 1H, $J_{3e,4}$ = 4.4 Hz, H-3e), 3.34 (s, 3H, MeO), 3.48 (q, 1H, $J_{4,5}$ = $J_{5,6}$ = $J_{5,NH}$ = 10.3 Hz, H-5), 3.62 (m, 1H, H-4), 3.81 (s, 3H, MeOCO), 4.02

(dd, 1H, $J_{6,7}$ 1.7 Hz, H-6), 4.16, 4.33 (2dd, 2H, $J_{8,9}$ = 5.0 Hz, $J_{8,9'}$ = 2.4 Hz, $J_{9,9'}$ 12.5 Hz, H-9,9'), 5.31 (dd, 1H, $J_{7,8}$ = 8.5 Hz, H-7), 5.39 (m, 1H, H-8), and 5.60 (d, 1H, NH).

Anal. Calcd for $C_{20}H_{31}NO_{11}S$ (493.5): C, 48.67; H, 6.33; N, 2.84. Found: C, 48.51; H, 6.29; N, 2.93.

Methyl (Methyl 5-Acetamido-7-O-acetyl-4,8-di-O-benzoyl-3,5-dideoxy-9-O-methyl-2-thio-D-glycero-α-D-galacto-2-nonulopyranosid)-onate (11). Acetylation of **7** (1.42 g, 2.49 mmol) with acetic anhydride (6 mL)-pyridine (10 mL) overnight at room temperature gave **11** (1.48 g, 97.5%) as an amorphous mass; $[\alpha]_D$ +69.5° (*c* 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.76 (s, 3H, AcN), 2.20, 2.22 (2s, 6H, AcO, MeS), 2.93 (dd, 1H, $J_{3a,3e}$ = 12.6 Hz, $J_{3e,4}$ = 4.7 Hz, H-3e), 3.33 (s, 3H, MeO), 3.54 (s, 3H, MeOCO), 3.56, 3.85 (2dd, 2H, $J_{8,9}$ = 7.7 Hz, $J_{8,9'}$ = 3.4 Hz, $J_{9,9'}$ = 11.0 Hz, H-9,9'), 4.00 (dd, 1H, $J_{5,6}$ = 10.7 Hz, $J_{6,7}$ = 2.3 Hz, H-6), 4.35 (q, 1H, $J_{4,5}$ = $J_{5,6}$ = $J_{5,NH}$ = 10.6 Hz, H-5), 5.12 (ddd, 1H, H-4), 5.47 (d, 1H, NH), 5.54 (dd, 1H, $J_{7,8}$ = 7.0 Hz, H-7), 5.66 (m, 1H, H-8), and 7.35-8.08 (m, 10H, 2Ph).

Anal. Calcd for $C_{30}H_{35}NO_{11}S$ (617.7): C, 58.33; H, 5.71; N, 2.27. Found: C, 58.40; H, 5.69; N, 2.21.

Methyl (Methyl 5-Acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-2-thio-L-glycero-α-D-galacto-2-nonulopyranosid)onate (12). To a solution of **9** (5.0 g, 1.0 mmol) in *N,N*-dimethylformamide (DMF; 50 mL) were added cesium acetate (10 g) and 18-crown-6 (4 g), and the mixture was heated, with stirring, for 24 h at 120 °C, and the precipitate was filtered off, and washed with CH_2Cl_2 (100 mL). The combined filtrate and washings were concentrated, and the residue was dissolved in DMF (50 mL). Methyl *p*-toluenesulfonate (10 g) and triethylamine (10 mL) were added, and the solution was stirred overnight at room temperature. Acetic anhydride (10 mL) and pyridine (20 mL) were added into the mixture, and this was stirred overnight at room temperature, and then concentrated to a syrup which was extracted with CH_2Cl_2 (200 mL). The extract was successively washed with 2 M HCl and water, dried (Na_2SO_4), and concentrated. Column chromatography (3 : 2 AcOEt-hexane) of the residue on silica gel (250 g) gave **12** (4.8 g, 91%) as an amorphous mass; $[\alpha]_D$ +0.6° (*c* 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.88 (s, 3H, AcN), 2.02, 2.04, 2.10, 2.11, 2.18 (5s, 15H, 4AcO, MeS), 2.78 (dd, 1H, $J_{3a,3e}$ = 12.6 Hz, $J_{3e,4}$ = 4.8 Hz, H-3e), 3.84 (s, 3H, MeOCO), 3.86 (dd, 1H, $J_{5,6}$ = 10.4 Hz, $J_{6,7}$ = 2.2 Hz, H-6), 4.06 (q, 1H, $J_{4,5}$ = $J_{5,6}$ = $J_{5,NH}$ = 10.4 Hz, H-5), 4.60 (m, 2H, H-9,9'), 4.93 (ddd, 1H, H-4), 5.33 (dd, 1H, $J_{7,8}$ = 9.0 Hz, H-7), and 5.38-5.50 (m, 2H, H-8, NH).

Anal. Calcd for $C_{21}H_{31}O_{14}NS$ (553.3): C, 45.58; H, 5.65; N, 2.53. Found: C, 45.61; H, 5.79; N, 2.48.

2-(Trimethylsilyl)ethyl O-(Methyl 5-Acetamido-7,8,9-tri-O-acetyl-3,5-dideoxy-4-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-2,6-di-O-benzoyl-β-D-glucopyranoside (14). To a solution of 2-(trimethylsilyl)ethyl *O*-(6-*O*-benzoyl-β-D-galactopyranosyl)-(1→4)–2,6-di-*O*-benzoyl-β-D-glucopyranoside[16] (**13**; 900 mg, 1.19 mmol) and **10** (1.2 g, 2.43 mmol) in dry MeCN (12 mL) was added molecular sieves 3 Å (MS-3Å; 4.0 g). The mixture was stirred overnight at room temperature and then cooled to -30 °C. To the cooled mixture was added, with stirring a mixture (3.5 g, 50% DMTST by weight) of dimethyl(methylthio)sulfonium triflate[17b] (DMTST) and MS-3 Å, and the stirring was continued for 24 h at -15 °C. The precipitate was filtered off, and washed thoroughly with CH_2Cl_2. The combined filtrate and washings were successively washed with M Na_2CO_3 and water, dried (Na_2SO_4), and concentrated. Column chromatography (3 : 1 AcOEt-hexane) of the residue on silica gel (60 g) gave **14** (540 g, 38%) as an amorphous mass; $[\alpha]_D$ +12.6° (*c* 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$) lactose unit δ 0.98 (m, 2 H, $Me_3SiCH_2CH_2$), 3.70 (m, 1H, $Me_3SiCH_2CH_2$), 4.70 (d, 1H, $J_{1',2'}$ = 7.9 Hz, H-1'), 4.76 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1), 5.38 (dd, 1H, $J_{2,3}$ = 9.5 Hz, H-2), and 7.38-8.20 (m, 15H, 3Ph); sialic acid unit δ 1.86 (t, 1H, $J_{3a,3e}$ = $J_{3a,4}$ = 13.2 Hz, H-3a), 2.07 (s, 3H, AcN), 2.09, 2.18, 2.25 (3s, 9H, 3AcO), 3.45 (s, 3H, MeO), 3.90 (s, 3H, MeOCO), 5.06 (dd, 1H, $J_{6,7}$ = 1.0 Hz, $J_{7,8}$ 10.0 Hz, H-7), 5.43 (m, 1H, H-8), and 5.80 (d, 1H, NH).

Anal. Calcd for $C_{57}H_{73}NO_{25}Si$ (1200.3): C, 57.03; H, 6.13; N, 1.17. Found: C, 56.79; H, 6.24; N, 1.03.

2-(Trimethylsilyl)ethyl O-(Methyl 5-Acetamido-7,8,9-tri-O-acetyl-3,5-dideoxy-4-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-3-O-acetyl-2,6-di-O-benzoyl-β-D-glucopyranoside (15). Compound **14** (500 mg, 0.42 mmol) was acetylated with Ac_2O (6 mL) in pyridine (9 mL) overnight at room temperature. The product was purified by chromatography on silica gel (50 g) with 200 : 3 CH_2Cl_2-MeOH, to give **15** (480 mg, 87%) as an amorphous mass; $[\alpha]_D$ +20.5° (*c* 0.73, $CHCl_3$); ^1H NMR ($CDCl_3$) lactose unit δ 0.98 (m, 2 H, $Me_3SiCH_2CH_2$), 3.68 (m, 1H, $Me_3SiCH_2CH_2$), 4.71 (dd, 1H, $J_{2',3'}$ = 10.3 Hz, $J_{3',4'}$ = 3.3 Hz, H-3'), 4.78 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1), 5.00 (d, 1H, $J_{1',2'}$ = 8.1 Hz, H-1'), 5.12 (broad d, 1H, H-4'), 5.15 (dd, 1H, H-2'), 5.33 (d, 1H, $J_{2,3}$ = 9.5 Hz, H-2), 5.59 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.5 Hz, H-3), and 7.38-8.19 (m, 15H, 3Ph); sialic acid unit δ 1.47 (t, 1H, $J_{3a,3e}$ = $J_{3a,4}$ = 12.5 Hz, H-3a), 2.04 (s, 3H, AcN), 2.86 (dd, 1H, $J_{3e,4}$ = 4.0 Hz, H-3e), 3.40 (s, 3H, MeO), 3.68 (m, 1H, H-4), 3.82 (s, 3H, MeOCO), 5.45 (dd, 1H, $J_{6,7}$ = 2.6 Hz, $J_{7,8}$ = 9.1 Hz, H-7), and 5.69 (m, 1H, H-8); *O*-acetyl groups δ 2.09, 2.13, 2.14, 2.15, 2.25, and 2.29 (6s, 18H, 6AcO).

Anal. Calcd for $C_{63}H_{79}NO_{28}Si$ (1326.4): C, 57.04; H, 6.00; N, 1.06. Found: C, 56.88; H, 6.05; N, 1.13.

O-(Methyl 5-Acetamido-7,8,9-tri-O-acetyl-3,5-dideoxy-4-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-3-O-acetyl-2,6-di-O-benzoyl-D-glucopyranose (16). To a stirred solution of **15** (440 mg, 0.33 mmol) in CH_2Cl_2 (10 mL), cooled to 0 °C, was added dropwise $BF_3 \cdot OEt_2$ (0.5 mL). The mixture was stirred for 4 h at 0 °C; the course of the reaction was monitored by TLC. Dichloromethane (100 mL) was added to the mixture, and the solution was successively washed with M Na_2CO_3 and water, dried (Na_2SO_4), and concentrated. Column chromatography (45 : 1 CH_2Cl_2-MeOH) of the residue on silica gel (70 g) gave **16** (365 mg, 89%) as an amorphous mass; $[\alpha]_D$ +61.0° (*c* 0.2, $CHCl_3$); IR (KBr) 3600-3300 (OH, NH), 1740 and 1230 (ester), 1660 and 1540 (amide), and 710 cm^{-1} (Ph).

Anal. Calcd for $C_{58}H_{67}NO_{28}$ (1226.2): C, 56.81; H, 5.51; N, 1.14. Found: C, 56.85; H, 5.49; N, 1.18.

O-(Methyl 5-Acetamido-7,8,9-tri-O-acetyl-3,5-dideoxy-4-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-3-O-acetyl-2,6-di-O-benzoyl-α-D-glucopyranosyl trichloroacetimidate (17). To a stirred solution of **16** (300 mg, 0.24 mmol) in CH_2Cl_2 (3 mL), cooled to 0 °C, were added Cl_3CCN (0.9 mL) and 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU; 35 mg). The mixture was stirred for 2 h at 0 °C, and then concentrated. Column chromatography (60 : 1 CH_2Cl_2-MeOH) of the residue on silica gel (30 g) gave **17** (270 mg, 81%) as an amorphous mass; $[\alpha]_D$ +54.6° (*c* 1.0, $CHCl_3$); IR (KBr) 3400 (NH), 1740 and 1220 (ester), 1670 and 1550 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) lactose unit δ 4.60 (dd, 1H, $J_{2',3'}$ = 10.3 Hz, $J_{3',4'}$ = 3.3 Hz, H-3'), 4.93 (d, 1H, $J_{1',2'}$ = 7.9 Hz, H-1'), 5.03 (broad d, 1H, H-4'), 5.07 (dd, 1H, H-2'), 5.28 (dd, 1H, $J_{2,3}$ = 9.7 Hz, H-2), 5.85 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.7 Hz, H-3), 6.66 (d, 1H, $J_{1,2}$ = 3.7 Hz, H-1), 7.27-8.12 (m, 15H, 3Ph), and 8.55 (s, 1H, C=NH); sialic acid unit δ 1.70 (t, 1H, $J_{3a,3e}$ = $J_{3a,4}$ = 12.4 Hz, H-3a), 1.93 (s, 3H, AcN), 2.74 (dd, 1H, $J_{3e,4}$ = 4.6 Hz, H-3e), 3.28 (s, 3H, MeO), 3.56 (m, 1H, H-4), 3.70 (s, 3H, MeOCO), 5.25 (d, 1H, NH), 5.33 (dd, 1H, $J_{6,7}$ = 2.4 Hz, $J_{7,8}$ = 8.9 Hz, H-7), and 5.54 (m, 1H, H-8); *O*-acetyl groups δ 1.96, 2.00, 2.01, 2.06, 2.15, and 2.16 (6s, 18H, 6AcO).

Anal. Calcd for $C_{60}H_{67}N_2O_{28}Cl_3$ (1370.5): C, 52.58; H, 4.93; N, 2.04. Found: C, 52.41; H, 5.11; N, 2.09.

2-(Trimethylsilyl)ethyl O-(Methyl 5-Acetamido-7-O-acetyl-4,8-di-O-benzoyl-3,5-dideoxy-9-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-2,6-di-O-benzoyl-β-D-glucopyranoside (18). Glycosylation of **13** (620 mg, 0.82 mmol) with **11** (1.0 g, 1.62 mmol) in CH_3CN (12 mL) in the presence of DMTST (1.8 g) and MS-3Å (4.7 g) for 24 h at - 15 °C, as described for **14**, gave compound **18** (530 mg, 50%) as an amorphous mass; $[\alpha]_D$ +28.0° (*c* 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$) lactose unit δ 0.98 (m, 2H, $Me_3SiCH_2CH_2$), 4.76 (d, 1H, $J_{1',2'}$ = 7.7 Hz, H-1'), 4.77 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1), and 5.37 (dd, 1H, $J_{2,3}$ = 9.5 Hz, H-2); sialic acid unit δ 1.92 (s, 3H, AcN), 2.31 (s, 3H, AcO), 2.87 (dd, 1H, $J_{3a,3e}$ = 12.8 Hz, $J_{3e,4}$ = 4.2 Hz, H-3e), 3.35, 3.39 (2s, 6H, MeO, MeOCO), 5.17 (dd, 1H, $J_{6,7}$ = 1.2 Hz, $J_{7,8}$ = 10.0 Hz, H-7), and 5.36 (m, 1H, H-4), and 5.73 (m, 1H, H-8); *O*-benzoyl groups δ 7.37-8.21 (m, 25H, 5Ph).

Anal. Calcd for $C_{67}H_{77}NO_{25}Si$ (1324.5): C, 60.75; H, 5.86; N, 1.06. Found: C, 60.63; H, 6.00; N, 1.02.

2-(Trimethylsilyl)ethyl O-(Methyl 5-Acetamido-7-O-acetyl-4,8-di-O-benzoyl-3,5-dideoxy-9-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-D-galactopyranosyl)-(1→4)-3-O-acetyl-2,6-di-O-benzoyl-β-D-glucopyranoside (19). Acetylation of **18** (380 mg, 0.29 mmol) with Ac_2O (6 mL)-pyridine (8 mL) overnight at room temperature, and a similar work up, as described for **15**, gave **19** (400 mg, 96%) as an amorphous mass; $[\alpha]_D$ +37.5° (*c* 0.5, $CHCl_3$); ^1H NMR ($CDCl_3$) lactose unit δ 0.97 (m, 2H, $Me_3SiCH_2CH_2$), 4.80 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1), 5.08 (broad d, 1H, H-4'), 5.10 (d, 1H, $J_{1',2'}$ = 7.9 Hz, H-1'), 5.20 (dd, 1H, $J_{2',3'}$ = 9.5 Hz, H-2'), 5.37 (dd, 1H, $J_{2,3}$ = 9.5 Hz, H-2), and 5.60 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.5 Hz, H-3); sialic acid unit δ 1.87 (s, 3H, AcN), 2.83 (dd, 1H, $J_{3a,3e}$ = 12.4 Hz, $J_{3e,4}$ = 4.5 Hz, H-3e), 3.39, 3.42 (2s, 6H, MeO, MeOCO), 5.20 (m, 1H, H-4), 5.73 (dd, 1H, $J_{6,7}$ = 2.6 Hz, $J_{7,8}$ = 9.4 Hz, H-7), and 5.86 (m, 1H, H-8); *O*-acyl groups δ 2.16, 2.19, 2.20, 2.43 (4s, 12H, 4AcO), and 7.29-8.16 (m, 25H, 5Ph).

Anal. Calcd for $C_{73}H_{83}NO_{28}Si$ (1450.6): C, 60.44; H, 5.77; N, 0.97. Found: C, 60.41; H, 5.88; N, 1.01.

O-(Methyl 5-Acetamido-7-O-acetyl-4,8-di-O-benzoyl-3,5-dideoxy-9-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-3-O-acetyl-2,6-di-O-benzoyl-D-glucopyranose (20). Selective removal of the 2-

(trimethylsilyl)ethyl group in **19** (390 mg, 0.27 mmol) with BF$_3$·OEt$_2$ (0.5 mL) in CH$_2$Cl$_2$ (7 mL) as described for **16**, gave compound **20** (340 mg, 94%) as an amorphous mass; $[\alpha]_D$ +67.9° (*c* 1.5, CHCl$_3$); IR (KBr) 3600-3300 (OH, NH), 1740 and 1220 (ester), 1670 and 1530 (amide), and 710 cm^{-1} (Ph).

Anal. Calcd for C$_{68}$H$_{71}$NO$_{28}$ (1350.3): C, 60.48; H, 5.30; N, 1.04. Found: C, 60.32; H, 5.48; N, 1.00.

O-(Methyl 5-Acetamido-7-O-acetyl-4,8-di-O-benzoyl-3,5-dideoxy-9-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-3-O-acetyl-2,6-di-O-benzoyl-α-D-glucopyranosyl trichloroacetimidate (21). To a stirred solution of **20** (340 mg, 0.25 mmol) in CH$_2$Cl$_2$ (4 mL), cooled to 0 °C, were added Cl$_3$CCN (0.9 mL) and DBU (40 mg), and the mixture was stirred for 2 h at 0 °C. A similar processing, as described for **17**, gave **21** (330 mg, 88%) as an amorphous mass; $[\alpha]_D$ +72.5° (*c* 0.68, CHCl$_3$); ^{1}H NMR (CDCl$_3$) lactose unit δ 4.78 (dd, 1H, $J_{2',3'}$ = 9.7 Hz, $J_{3',4'}$ = 3.1 Hz, H-3'), 4.97 (broad d, 1H, H-4'), 5.02 (d, 1H, $J_{1',2'}$ = 7.9 Hz, H-1'), 5.03 (dd, 1H, H-2'), 5.32 (dd, 1H, $J_{1,2}$ = 3.7 Hz, $J_{2,3}$ = 10.3 Hz, H-2), 5.86 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.5 Hz, H-3), 6.68 (d, 1H, H-1), and 8.56 (s, 1H, C=NH); sialic acid unit δ 1.75 (s, 3H, AcN), 2.72 (dd, 1H, $J_{3a,3e}$ = 12.6 Hz, $J_{3e,4}$ = 5.6 Hz, H-3e), 3.26, 3.32 (2s, 6H, MeO, MeOCO), 3.72 (dd, 1H, $J_{5,6}$ = 10.9 Hz, $J_{6,7}$ = 2.7 Hz, H-6), 5.62 (dd, 1H, $J_{7,8}$ = 9.7 Hz, H-7), and 5.37 (m, 1H, H-8); *O*-acyl groups δ 2.08, 2.09, 2.10, 2.32 (4s, 12H, 4AcO), and 7.18-8.11 (m, 25H, 5Ph).

Anal. Calcd for C$_{70}$H$_{71}$N$_2$O$_{28}$Cl$_3$ (1494.7): C, 56.24; H, 4.79; N, 1.87. Found: C, 56.09; H, 4.91; N, 1.83.

2-(Trimethylsilyl)ethyl O-(Methyl 5-Acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-L-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-2,6-di-O-benzoyl-β-D-glucopyranoside (22). Glycosylation of **13** (350 mg, 0.46 mmol) with **12** (500 mg, 0.9 mmol) in CH$_3$CN (6 mL) in the presence of DMTST (750 mg) and MS-3Å (4.5 g) for 24 h at -15 °C, as described for **14**, gave compound **22** (320 mg, 55%) as an amorphous mass; $[\alpha]_D$ -11.5° (*c* 1.0, CHCl$_3$); ^{1}H NMR (CDCl$_3$) lactose unit δ 0.98 (m, 2H, Me$_3$SiC*H*$_2$CH$_2$), 3.68 (m, 1H, Me$_3$SiCH$_2$C*H*$_2$), 4.69 (d, 1H, $J_{1',2'}$ = 7.9 Hz, H-1'), 4.76 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1), 5.33 (dd, 1H, $J_{2,3}$ = 9.5 Hz, H-2), and 7.47~8.20 (m, 15H, 3Ph); sialic acid unit δ 1.97 (s, 3H, AcN), 2.12, 2.13, 2.15, 2.21 (4s, 12H, 4AcO), 2.82 (dd, 1H, $J_{3a,3e}$ = 12.6 Hz, $J_{3e,4}$ = 4.8 Hz, H-3e), 3.97 (s, 3H, MeOCO), 5.13 (ddd, 1H, $J_{4,5}$ = 10.4 Hz, H-4), 5.33 (dd, $J_{6,7}$ = 3.0 Hz, $J_{7,8}$ = 8.8 Hz, H-7), and 5.57 (m, 1H, H-8).

Anal. Calcd for $C_{58}H_{73}NO_{26}Si$ (1228.3): C, 56.72; H, 5.99; N, 1.14. Found: C, 56.79; H, 6.16; N, 1.10.

A sample of **22** (130 mg, 0.11 mmol) was acetylated with Ac_2O (3 mL)-pyridine (5 mL) overnight at room temperature. A similar processing, as described for **15**, gave **23** (130 mg, 95%) as an amorphous mass; $[\alpha]_D$ -11.5° (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$) lactose unit δ 0.98 (m, 2H, $Me_3SiCH_2CH_2$), 3.68 (m, 1H, $Me_3SiCH_2CH_2$), 4.81 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1), 5.05 (d, 1H, $J_{1',2'}$ = 8.1 Hz, H-1'), 5.21 (dd, 1H, $J_{2',3'}$ = 10.0 Hz, H-2'), 5.32 (broad d, 1H, H-4'), 5.34 (dd, 1H, $J_{2,3}$ = 9.7 Hz, H-2), 5.60 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.7 Hz, H-3), and 7.47-8.20 (m, 15H, 3Ph); sialic acid unit δ 1.97 (s, 3H, AcN), 2.72 (dd, 1H, $J_{3a,3e}$ = 12.6 Hz, $J_{3e,4}$ = 4.8 Hz, H-3), 3.76 (dd, 1H, $J_{5,6}$ = 10.5 Hz, $J_{6,7}$ = 2.5 Hz, H-6), 3.95 (s, 3H, MeOCO), 5.32 (dd, 1H, $J_{7,8}$ = 9.7 Hz, H-7), and 5.77 (dt, 1H, $J_{7,8}$ = $J_{8,9}$ = 9.7 Hz, $J_{8,9'}$ = 2.0 Hz, H-8); *O*-acetyl groups δ 2.03, 2.14 (2), 2.15, 2.16, 2.28, 2.31 (7s, 21H, 7AcO).

Anal. Calcd for $C_{64}H_{79}NO_{29}Si$ (1354.4): C, 56.76; H, 5.88; N, 1.03. Found: C, 56.68; H, 5.91; N, 1.05.

O-(Methyl 5-Acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-L-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-3-O-acetyl-2,6-di-O-benzoyl-D-glucopyranose (24). Selective removal of the 2-(trimethylsilyl)ethyl group in **23** (380 mg, 0.28 mmol) with $BF_3 \cdot OEt_2$ (0.3 mL) in CH_2Cl_2 (8 mL), as described for **16**, gave **24** (330 mg, 94%) as an amorphous mass; $[\alpha]_D$ +29.0° (*c* 1.1, $CHCl_3$); IR (KBr) 3700-3200 (OH, NH), 1750 and 1230 (ester), 1670 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$); lactose unit δ 5.08 (near t, 1H, $J_{1',2'}$ = $J_{2',3'}$ = 8.5 Hz, H-2'), 5.47 (broad d, 1H, H-4'), 5.80 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.5 Hz, H-3); sialic acid unit δ 2.57 (dd, 1H, $J_{3a,3e}$ = 12.8 Hz, $J_{3e,4}$ = 4.7 Hz, H-3e), 3.58 (dd, 1H, $J_{5,6}$ = 10.6 Hz, $J_{6,7}$ = 2.2 Hz, H-6), 3.78 (s, 3H, MeOCO), 5.18 (m, 1H, H-7), and 5.60 (m, 1H, H-8).

Anal. Calcd for $C_{59}H_{67}NO_{22}$ (1254.2): C, 56.50; H, 5.38; N, 1.12. Found: C, 56.41; H, 5.44; N, 1.19.

O-(Methyl 5-Acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-L-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-3-O-acetyl-2,6-di-O-benzoyl-α-D-glucopyranosyl trichloroacetimidate (25). To a stirred solution of **24** (300 mg, 0.24 mmol) in CH_2Cl_2 (3 mL), cooled to 0 °C, were added Cl_3CCN (0.8 mL) and DBU (35 mg), and the mixture was stirred for 2 h at 0 °C. A similar processing, as described for **17**, gave **25** (320 mg, 96%) as an amorphous mass; $[\alpha]_D$ +24.2° (*c* 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$) lactose unit δ 4.98 (d, 1H, $J_{1',2'}$ = 8.1 Hz, H-1'), 5.10

(dd, 1H, $J_{2',3'}$ = 9.9 Hz, H-2'), 5.19 (broad d, 1H, H-4'), 5.26 (dd, 1H, $J_{1,2}$ = 3.9 Hz, $J_{2,3}$ = 9.7 Hz, H-2), 5.83 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.7 Hz, H-3), 6.64 (d, 1H, H-1), 7.31-8.11 (m, 15H, 3Ph), and 8.55 (s, 1H, C=NH); sialic acid unit δ 1.70 (t, 1H, $J_{3a,3e}$ = $J_{3a,4}$ = 12.4 Hz, H-3a), 1.82 (s, 3H, AcN), 2.60 (dd, 1H, $J_{3e,4}$ = 4.9 Hz, H-3e), 3.59 (dd, 1H, $J_{5,6}$ = 10.4 Hz, $J_{6,7}$ = 2.4 Hz, H-6), 3.80 (s, 3H, MeOCO); 5.18 (dd, 1H, $J_{7,8}$ = 7.9 Hz, H-7), and 5.61 (dt, 1H, $J_{7,8}$ = $J_{8,9}$ = 7.9 Hz, $J_{8,9'}$ = 2.0 Hz, H-8), and 6.46 (d, 1H, NH); *O*-acetyl groups δ 1.93, 1.97, 1.98, 2.00, 2.05, 2.14, and 2.22 (7s, 31H, 7AcO).

Anal. Calcd for $C_{61}H_{67}N_2O_{29}Cl_3$ (1398.6): C, 52.39; H, 4.83; N, 2.00. Found: C, 53.13; H, 4.98; N, 2.05.

O-(Methyl 5-Acetamido-7,8,9-tri-O-acetyl-3,5-dideoxy-4-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-O-(3-O-acetyl-2,6-di-O-benzoyl-β-D-glucopyranosyl)-(1→1)-(2S,3R,4E)-2-azido-3-O-benzoyl-4-octadecene-1,3-diol (27). To a solution of **17** (120 mg, 0.09 mmol) and (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol[29,30] (**26**; 80 mg, 0.19 mmol) in dry CH_2Cl_2 (3.5 mL) was added MS-4Å (type AW 300; 2.5 g), and the mixture was stirred for 30 min at room temperature, and then cooled to 0 °C. Boron trifluoride etherate (0.05 mL) was added to the mixture, and this was stirred for 5 h at 0 °C. After completion of the reaction, the precipitate was filtered off and washed thoroughly with CH_2Cl_2. The solution was washed successively with M Na_2CO_3 and water, dried (Na_2SO_4), and concentrated. Column chromatography (70 : 1 CH_2Cl_2-MeOH) of the residue on silica gel (20 g) gave **27** (100 mg, 70%) as an amorphous mass; $[\alpha]_D$ +10.0° (*c* 1.3, $CHCl_3$); IR (KBr) 3300 (NH), 2940 and 2850 (Me, methylene), 2100 (N_3), 1740 and 1230 (ester), 1680 and 1550 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) lactose unit δ 4.40 (dd, 1H, $J_{2',3'}$ = 10.3 Hz, $J_{3',4'}$ = 3.3 Hz, H-3'), 4.66 (d, 1H, $J_{1,2}$ = 7.3 Hz, H-1), 4.93 (d, 1H, $J_{1',2'}$ = 7.7 Hz, H-1'), 5.01 (broad d, 1H, H-4'), 5.04 (dd, 1H, H-2'), and 5.25 (dd, 1H, $J_{2,3}$ = 9.9 Hz, H-3); sialic acid unit δ 1.98 (s, 3H, AcN), 2.73 (dd, 1H, $J_{3a,3e}$ = 12.5 Hz, $J_{3e,4}$ = 3.7 Hz, H-3), 3.28 (s, 3H, MeO), 3.54 (m, 1H, H-4), 3.69 (s, 3H, MeOCO), and 5.61 (m, 1H, H-8); sphingosine unit δ 0.87 (t, 3H, *Me*CH_2), 1.24 (s, 22H, 11 CH_2), and 5.66 (m, 1H, $J_{5,6}$ = $J_{5,6'}$ = 7.0 Hz); *O*-acyl groups δ 1.98, 2.01, 2.03 (2), 2.13, 2.16 (6s, 18H, 6AcO), and 7.27-8.06 (m, 20H, 4Ph).

Anal. Calcd for $C_{83}H_{104}N_4O_{30}$ (1637.8): C, 60.87; H, 6.40; N, 3.42. Found: C, 60.77; H, 6.41; N, 3.58.

O-(Methyl 5-Acetamido-7,8,9-tri-O-acetyl-3,5-dideoxy-4-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-

acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-O-(3-O-acetyl-2,6-di-O-benzoyl-β-D-glucopyranosyl)-(1→1)-(2S,3R,4E)-3-O-benzoyl-2-octadecanamido-4-octadecene-1,3-diol (28). Hydrogen sulfide was bubbled through a solution of **27** (100 mg, 0.06 mmol) in pyridine (5 mL) and water (2 mL) for 25 h while the solution was stirred at room temperature; the course of the reaction was monitored by TLC. The mixture was concentrated to give the syrupy amine, which was used for the next reaction without further purification. To a solution of the amine in dry CH_2Cl_2 (6 mL) were added octadecanoic acid (58 mg, 0.2 mmol) and 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (WSC; 58 mg), and the mixture was stirred overnight at room temperature. After completion of the reaction, CH_2Cl_2 (100 mL) was added to the mixture, and the solution was washed with water, dried (Na_2SO_4), and concentrated. Column chromatography (75 : 1 CH_2Cl_2-MeOH) of the residue on silica gel (30 g) gave **28** (93 mg, 81%) as an amorphous mass; $[\alpha]_D$ +18.0° (*c* 1.1, $CHCl_3$); ^1H NMR ($CDCl_3$) lactose unit δ 4.59 (dd, 1H, $J_{2',3'}$ = 9.9 Hz, $J_{3',4'}$ = 3.3 Hz, H-3'), 4.61 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1), 4.84 (d, 1H, $J_{1',2'}$ = 8.1 Hz, H-1'), 5.00 (broad d, 1H, H-4'), 5.01 (dd, 1H, H-2'), 5.19 (dd, 1H, $J_{2,3}$ = 9.9 Hz, H-2), and 5.47 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.9 Hz, H-3e); sialic acid unit δ 1.93 (s, 3H, AcN), 2.73 (dd, 1H, $J_{3a,3e}$ = 12.6 Hz, $J_{3e,4}$ = 4.2 Hz, H-3), 3.29 (s, 3H, MeO), 3.56 (m, 1H, H-4), 3.70 (s, 3H, MeOCO), 5.35 (dd, 1H, $J_{6,7}$ = 2.6 Hz, $J_{7,8}$ 9.1 Hz, H-7), 5.56 (m, 1H, H-8), and 5.65 (d, 1H, NH); Cer unit δ 0.87 (t, 6H, 2*Me*CH_2), 1.26 (s, 50H, 25CH_2), and 5.76 (dt, 1H, $J_{4,5}$ = 14.5 Hz, $J_{5,6}$ = $J_{5,6'}$ = 7.0 Hz, H-5); *O*-acyl groups δ 1.99, 2.01, 2.02, 2.03, 2.13 (2) (6s, 18H, 6AcO), and 7.25-8.06 (m, 20H, 4Ph).

Anal. Calcd for $C_{101}H_{140}N_2O_{31}$ (1878.2): C, 64.58; H, 7.51; N, 1.49. Found: C, 64.41; H, 7.63; N, 1.51.

O-(5-Acetamido-3,5-dideoxy-4-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonic acid)-(2→3)-O-β-D-galactopyranosyl)-(1→4)-O-β-D-glucopyranosyl-(1→1)-(2S,3R,4E)-2-octadecanamido-4-octadecene-1,3-diol (29). To a solution of **28** (85 mg, 0.045 mmol) in MeOH (3 mL) was added NaOMe (20 mg) and the mixture was stirred for 22 h at room temperature; the course of the reaction was monitored by TLC. Water (0.5 mL) was added to the mixture, and this was stirred for 20 h at room temperature, neutralized with Amberlite IR-120 (H^+) resin and filtered. The resin was washed with MeOH, and the combined filtrate and washings were concentrated. Column chromatography (MeOH) of the residue on Sephadex LH-20 (40 g) gave **29** (52 mg, quantitative) as an amorphous mass; $[\alpha]_D$ +3.0° (*c* 0.9, 1 : 1 MeOH-$CHCl_3$); IR (KBr) 3600-3400 (OH, NH), 2920 and 2850 (Me, methylene), 1730 (COOH), and 1630 and 1540 cm^{-1} (amide); ^1H NMR (1 : 1 $CDCl_3$-CD_3OD) lactose unit δ 4.10 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1) and 4.43 (d, 1H, $J_{1',2'}$ = 8.1 Hz, H-1'); sialic acid unit δ 2.00 (s, 3H, AcN), 2.99 (dd, 1H, $J_{3a,3e}$ = 12.5 Hz, $J_{3e,4}$ = 4.6 Hz, H-3e), and 3.40 (s, 3H, MeO); Cer unit δ 0.89 (t, 6H, 2*Me*CH_2), 1.28 (s, 50H, 25CH_2), 4.19 (dd, 1H, $J_{1,1'}$ = 9.9 Hz, $J_{1,2}$ = 4.0 Hz, H-1), 5.45 (dd, 1H, $J_{3,4}$ = 7.7 Hz, $J_{4,5}$ = 15.4 Hz, H-4), and 5.69 (dt, 1H, $J_{5,6}$ = $J_{5,6'}$ = 6.6 Hz, H-5).

Anal. Calcd for $C_{60}H_{110}N_2O_{21}$ (1195.6): C, 60.27; H, 9.27; N, 2.34. Found: C, 60.10; H, 9.41; N, 2.22.

O-(Methyl 5-Acetamido-7-O-acetyl-4,8-di-O-benzoyl-3,5-dideoxy-9-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-O-(3-O-acetyl-2,6-di-O-benzoyl-β-D-glucopyranocyl)-(1→1)-(2S,3R,4E)-2-azido-3-O-benzoyl-4-octadecene-1,3-diol (30). Coupling of **21** (200 mg, 0.13 mmol) and **26** (100 mg, 0.23 mmol), as described for **27**, gave compound **30** (190 mg, 81%) as an amorphous mass; $[\alpha]_D$ +23.6° (*c* 1.9, $CHCl_3$); IR (KBr) 3300 (NH), 2930 and 2850 (Me, methylene), 2100 (N_3), 1730 and 1220 (ester), 1680 and 1530 (amide), and 710 cm^{-1} (Ph); ^{1}H NMR ($CDCl_3$) lactose unit δ 4.71 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1), 4.77 (dd, 1H, $J_{2',3'}$ = 9.5 Hz, $J_{3',4'}$ = 3.3 Hz, H-3'), 4.96 (broad d, 1H, H-4'), 4.99 (d, 1H, $J_{1',2'}$ = 7.7 Hz, H-1'), 5.13 (dd, 1H, H-2'), 5.29 (dd, 1H, $J_{2,3}$ = 9.3 Hz, H-2), and 5.52 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.3 Hz, H-3); sialic acid unit δ 1.75 (s, 3H, AcN), 2.72 (dd, 1H, $J_{3a,3e}$ = 12.5 Hz, $J_{3e,4}$ = 4.4 Hz, H-3e), 3.27, 3.30 (2s, 6H, MeO, MeOCO), 3.42 (dd, 1H, $J_{8,9}$ = 3.7 Hz, $J_{9,9'}$ = 11.6 Hz, H-9), 5.62 (dd, 1H, $J_{6,7}$ = 2.8 Hz, $J_{7,8}$ = 9.4 Hz, H-7), and 5.74 (m, 1H, H-8); sphingosine unit δ 0.88 (t, 3H, *Me*CH_2), and 1.25 (s, 22H, 11CH_2); *O*-acyl groups δ 2.06, 2.07, 2.08, 2.31 (4s, 12H, 4AcO), and 7.17-8.06 (m, 30H, 6Ph).

Anal. Calcd for $C_{93}H_{108}N_4O_{30}$ (1761.9): C, 63.39; H, 6.18; N, 3.18. Found: C, 63.29; H, 6.21; N, 3.20.

O-(Methyl 5-Acetamido-7-O-acetyl-4,8-di-O-benzoyl-3,5-dideoxy-9-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-O-(3-O-acetyl-2,6-di-O-benzoyl-β-D-glucopyranosyl)-(1→1)-(2S,3R,4E)-3-O-benzoyl-2-octadecanamido-4-octadecene-1,3-diol (31). Selective reduction of the azide group in **30** (150 mg, 0.08 mmol) and subsequent coupling with octadecanoic acid (50 mg, 0.17 mmol), as described for **28**, afforded **31** (144 mg, 84%) as an amorphous mass; $[\alpha]_D$ +34.0° (*c* 2.8, $CHCl_3$); ^{1}H NMR ($CDCl_3$) lactose unit δ 4.63 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1), 4.77 (dd, 1H, $J_{2',3'}$ = 10.3 Hz, $J_{3',4'}$ = 3.3 Hz, H-3'), 4.96 (broad d, 1H, H-4'), 4.97 (d, 1H, $J_{1',2'}$ = 7.9 Hz, H-1'), 5.07 (dd, 1H, H-2'), 5.22 (dd, 1H, $J_{2,3}$ = 9.7 Hz, H-2), and 5.50 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.7 Hz, H-3); sialic acid unit δ 1.75 (s, 3H, AcN), 2.72 (dd, 1H, $J_{3a,3e}$ = 12.3 Hz, $J_{3e,4}$ = 4.4 Hz, H-3e), 3.27, 3.30 (2s, 6H, MeO, MeOCO), 3.45 (dd, 1H, $J_{8,9}$ = 3.5 Hz, 9,9' = 11.2 Hz, H-9), 3.71 (dd, 1H, $J_{5,6}$ = 10.4 Hz, $J_{6,7}$ = 2.9 Hz, H-6), 4.30 (q, 1H, $J_{4,5}$ = $J_{5,6}$ = $J_{5,NH}$ = 10.4 Hz, H-5), 5.63 (dd, 1H, $J_{7,8}$ = 9.9 Hz, H-7), and 5.78 (m, 1H, H-8); Cer unit δ 0.87 (t, 6H, 2*Me*CH_2), and 1.26 (s, 50H, 25CH_2), and 5.80 (m, 1H, H-5); *O*-acyl groups δ 2.05, 2.07, 2.09, 2.30 (4s, 12H, 4AcO), and 7.17-8.07 (m, 30H, 6Ph).

Anal. Calcd for $C_{111}H_{144}N_2O_{31}$ (2002.4): C, 66.58; H, 7.25; N, 1.40. Found: C, 66.61; H, 7.30; N, 1.38.

O-(5-Acetamido-3,5-dideoxy-9-O-methyl-D-glycero-α-D-galacto-2-nonulopyranosylonic acid)-(2→3)-O-β-D-galactopyranosyl-(1→4)-O-β-D-glucopyranosyl-(1→1)-(2S,3R,4E)-2-octadecanamido-4-octadecene-1,3-diol (32). Deacylation and saponification of **31** (140 mg, 0.07 mmol), as described for **29**, yielded compound **32** (79 mg, 94%) as an amorphous mass; $[\alpha]_D$ -0.5° (*c* 1.2, 1 : 1 MeOH-$CHCl_3$); IR (KBr) 3600-3300 (OH, NH), 2940 and 2850 (Me, methylene), 1730 (COOH), and 1640 and 1550 cm^{-1} (amide); ^1H NMR (1 : 1 $CDCl_3$-CD_3OD) lactose unit δ 4.30 (d, 1H, $J_{1,2}$ = 7.3 Hz, H-1), and 4.42 (d, 1H, $J_{1',2'}$ = 7.1 Hz, H-1'); sialic acid unit δ 2.03 (s, 3H, AcN), 2.79 (dd, 1H, $J_{3a,3e}$ = 12.5 Hz, $J_{3e,4}$ = 4.0 Hz, H-3e), and 3.41 (s, 3H, MeO); Cer unit δ 0.89 (t, 6H, 2*Me*CH_2), and 1.27 (s, 50H, 25CH_2), and 5.46 (dd, 1H, $J_{3,4}$ = 7.3 Hz, $J_{4,5}$ = 15.4 Hz, H-4), and 5.68 (dt, 1H, $J_{5,6}$ = $J_{5,6'}$ = 6.6 Hz, H-5).

Anal. Calcd for $C_{60}H_{110}N_2O_{21}$ (1195.6): C, 60.27; H, 9.27; N, 2.34. Found: C, 60.18; H, 9.40; N, 2.33.

O-(Methyl 5-Acetamido-4,7,8,9-tetra-O-acetyl-L-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-O-(2,4-di-O-acetyl-6-O-benzoyl-β-D-galactopyranosyl)-(1→4)-O-(3-O-acetyl-2,6-di-O-benzoyl-β-D-glucopyranosyl)-(1→1)-(2S,3R,4E)-2-azido-3-O-benzoyl-4-octadecene-1,3-diol (33). Coupling of **25** (210 mg, 0.15 mmol) and **26** (150 mg, 0.34 mmol), as described for **27**, gave **33** (200 mg, 80%) as an amorphous mass; $[\alpha]_D$ -19.6° (*c* 1.1, $CHCl_3$); IR (KBr) 3600-3400 (NH), 2940 and 2850 (Me, methylene), 2100 (N_3), 1740 and 1220 (ester), 1680 and 1530 (amide), and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) lactose unit δ 4.66 (d, 1H, $J_{1,2}$ = 8.1 Hz, H-1), 4.93 (d, 1H, $J_{1',2'}$ = 8.1 Hz, H-1'), 5.08 (dd, 1H, $J_{2',3'}$ = 10.7 Hz, H-2'), 5.16 (broad d, 1H, H-4'), 5.23 (dd, 1H, $J_{2,3}$ = 9.7 Hz, H-2), and 5.40 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.7 Hz, H-3); sialic acid unit δ 1.84 (s, 3H, AcN), 2.60 (dd, 1H, $J_{3a,3e}$ = 12.8 Hz, $J_{3e,4}$ = 4.9 Hz, H-3e), 3.52 (dd, 1H, $J_{8,9}$ = 3.6 Hz, $J_{9,9'}$ = 10.4 Hz, H-9), 3.56 (dd, 1H, $J_{5,6}$ = 10.4 Hz, $J_{6,7}$ = 2.2 Hz, H-6), 3.80 (s, 3H, MeOCO), 5.17 (dd, 1H, H-7), and 5.61 (m, 1H, H-8); sphingosine unit δ 0.87 (t, 3H, *Me*CH_2), 1.24 (s, 22H, 11CH_2), 5.51 (dd, 1H, H-4), and 5.55 (m, 1H, H-5); *O*-acyl groups δ 1.90, 1.98, 1.99, 2.00, 2.01, 2.12, 2.21 (7s, 21H, 7AcO), and 7.27-8.05 (m, 20H, 4Ph).

Anal. Calcd for $C_{84}H_{104}N_4O_{31}$ (1665.8): C, 60.57; H, 6.29; N, 3.36. Found: C, 60.40; H, 6.38; N, 3.34.

The azide group in **33** (100 mg, 0.06 mmol) was converted into amine, which was then condensed with octadecanoic acid (58 mg, 0.12 mmol), as described for **28**, afforded **34** (91 mg, 79%) as an amorphous mass; $[\alpha]_D$ -3.0° (*c* 0.8, $CHCl_3$); ^1H NMR ($CDCl_3$) lactose unit δ 4.59 (d, 1H, $J_{1,2}$ = 7.7 Hz, H-1), 4.91 (d, 1H, $J_{1',2'}$ = 7.7 Hz, H-1'), 5.06 (dd, 1H, $J_{2',3'}$ = 10.3 Hz, H-2'), 5.16 (broad d, 1H, H-4'), 5.17 (dd, 1H, $J_{2,3}$ = 10.6 Hz, H-2), and 5.37 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 10.6 Hz, H-3); sialic acid unit δ 1.84 (s, 3H, AcN), 2.59 (dd, 1H, $J_{3a,3e}$ = 12.6 Hz, $J_{3e,4}$ = 4.5 Hz, H-3e), 3.58 (dd, 1H, $J_{5,6}$ = 10.4 Hz, $J_{6,7}$ = 2.0 Hz, H-6), 3.80 (s, 3H, MeOCO), 4.95 (m, 1H, H-4), 5.18 (m, 1H, H-7), 5.60 (m, 1H, H-8), and 5.65 (d, 1H, NH); Cer unit δ 0.87 (t, 6H, 2 *Me*CH_2), 1.26 (s, 50H, 25CH_2), and 5.75 (dt, 1H, $J_{4,5}$ = 15.0 Hz, $J_{5,6}$ = $J_{5,6}$ = 6.8 Hz, H-5); *O*-acyl groups δ 1.91, 1.97, 1.99, 2.00, 2.01, 2.12, 2.19 (7s, 21H, 7AcO), and 7.26-8.04 (m, 20H, 4Ph).

Anal. Calcd for $C_{102}H_{140}N_2O_{32}$ (1906.2): C, 64.27; H, 7.40; N, 1.47. Found: C, 64.34; H, 7.48; N, 1.50.

O-(5-Acetamido-3,5-dideoxy-L-glycero-α-D-galacto-2-nonulopyranosylonic acid)-(2→3)-O-β-D-galactopyranosyl-(1→4)-O-β-D-glucopyranosyl-(1→1)-(2S,3R,4E)-2-octadecanamido-4-octadecene-1,3-diol (35). The *O*-acyl and methyl ester group in **34** (90 mg, 0.047 mmol) were removed, as described for **29**, to give compound **35** (53 mg, 95%) as an amorphous mass; $[\alpha]_D$ -0.7° (*c* 0.8, 1 : 1 MeOH-$CHCl_3$); IR (KBr) 3700-3200 (OH, NH), 2940 and 2850 (Me, methylene), 1730 (COOH), and 1650 and 1560 cm^{-1} (amide); ^1H NMR (1 : 1 $CDCl_3$-CD_3OD) lactose unit δ 4.17 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1) and 4.25 (d, 1H, $J_{1',2'}$ = 7.9 Hz, H-1'); sialic acid unit δ 1.86 (s, 3H, AcN) and 3.08 (dd, 1H, $J_{3a,3e}$ = 12.0 Hz, $J_{3e,4}$ = 4.4 Hz, H-3e); Cer unit δ 0.86 (t, 6H, $J_{Me,CH2}$ = 6.6 Hz, 2 *Me*CH_2), 1.24 (s, 50H, 25CH_2), 4.22 (dd, 1H, $J_{1,1'}$ = 10.0 Hz, $J_{1,2}$ = 4.3 Hz, H-1), 5.44 (dd, 1H, $J_{3,4}$ = 6.7 Hz, $J_{4,5}$ = 15.4 Hz, H-4), and 5.55 (dt, 1H, $J_{5,6}$ = $J_{5,6'}$ = 6.6 Hz, H-5).

Anal. Calcd for $C_{65}H_{120}N_2O_{21}$ (1277.6): C, 62.04; H, 9.47; N, 2.19. Found: C, 61.90; H, 9.67; N, 2.15.

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