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Total synthesis of ganglioside GQ1b and the related polysialogangliosides[1]

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Abstract: The first total synthesis of ganglio-series gangliosides GQ1b, GT1b and GD1b, which contain α-sialyl-(2→8)-α-sialic acid residue in the structure, will be described. Glycosylation of 2-(trimethylsilyl)ethyl *O*-(2-acetamido-6-*O*-benzyl-2-deoxy-3,4-*O*-isopropylidene-β-D-galactopyranosyl)- (1→4) -*O*-(2,6 -di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (**7**) with methyl [phenyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylono-1',9 -lactone) -4,7 -di-*O* -acetyl-3,5 -dideoxy-2- thio-D -*glycero* -D -*galacto* -2 -nonulopyranosid]onate (**8**) using *N*-iodosuccinimide (NIS)-trifluoromethanesulfonic acid (TfOH) in acetonitrile gave the protected GD2 pentasaccharide **9**, which was converted into the pentasaccharide acceptor **10** by de-*O*-isopropylidenation. Glycosylation of **10** with methyl thioglycoside derivatives **18, 26, 34** by use of dimethyl(methylthio)sulfonium triflate (DMTST) gave the protected ganglioside oligosaccharides **19, 27** and **35**, respectively. Compounds **9, 19, 27** and **35** were transformed into the corresponding α-trichloroacetimidates **13, 22, 30** and **38**, via reductive removal of benzyl groups, *O*-acetylation, selective removal of 2-(trimethylsilyl)ethyl group, and treatment of trichloroacetonitrile. Condensation of the imidates **13, 22, 30** and **38** with (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol (**14**) gave the corresponding β-glycosides **15, 23, 31** and **39**, which were converted, via selective reduction of azido group, coupling with octadecanoic acid, de-*O*-acylation, and saponification of methyl esters and lactone groups, into the corresponding gangliosides GD2 (**17**), GD1b (**25**), GT1b (**33**) and GQ1b (**41**).

INTRODUCTION

Ganglio-series gangliosides are distinguished from other gangliosides by consisting of gangliotriose: β-D-GalNAc-(1→4)-β-D-Gal-(1→4)-β-D-Glc, or gangliotetraose: β-D-Gal-(1→3)-β-D-GalNAc-(1→4)-β-D-Gal-(1→4)-β-D-Glc, which are sialylated at C-3 position of Gal , at C-6 position of GalNAc and at C-8 position of sialic acid residues. These gangliosides are first isolated from human brain[2-4] and bovine brain[5], and expressed in nervous cells of vertebrate animals. Recently, the biological roles of gangliosides in nervous system have documented[6-12] such as nerve growth factor (NGF)-like activity of ganglioside GQ1b in human neuloblastoma cell lines[12]. As biologically derived gangliosides are polymorphous and available in very limited quantity, the pure gangliosides which are synthesized by chemical methods have been required to elucidate the functions of gangliosides in details.

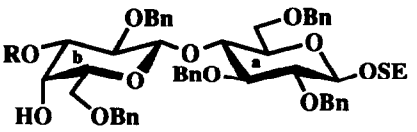
We have reported the α-glycosylation[13,14] of the suitably protected sugar residues with 2-thioglycosides of sialic acids by use of dimethyl(methylthio)sulfonium triflate (DMTST)[15] or *N*-iodosuccinimide (NIS)–trifluoromethanesulfonic acid (TfOH)[16] as the glycosyl promoter, and the syntheses[17-23] of a variety of gangliosides and their analogs in order to elucidate the structure–function relationships of gangliosides in the molecular level. Moreover, we have reported the α-glycosylation[24,25] of galactose and lactose derivatives with phenyl thioglycosides of dimeric and trimeric sialic acid as the donor using NIS-TfOH to give the di- and trisialyl oligosaccharide units for polysialo gangliosides synthesis, and the total syntheses of gangliosides GD3[24], GD2[26] and GQ1b[27], which contain α-sialyl-(2→8)-α-sialic acid residues. We describe herein the systematic synthesis of polysialo ganglio-series gangliosides.

RESULTS AND DISCUSSION

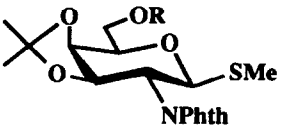
GD2 pentasaccharide acceptor **10** was selected as the key compound to achieve the systematic synthesis of polysialo ganglio-series gangliosides, which was condensed with the non-reductive sugar parts: methyl thioglycosides of Gal, Neu5Acα(2→3)Gal and Neu5Acα(2→8)Neu5Acα(2→3)Gal, transformed into the title compounds. Although ganglioside GD2 have already been synthesized by Matsuzaki et al[28] and us[26] by coupling galactosamine and α-sialyl-(2→8)-α-sialyl-(2→3')-lactose derivative, we attempt the α-glycosylation of gangliotriose acceptor **7** with α-sialyl-(2→8)-sialic acid donor[24] **8** to prepare the GD2 pentasaccharide **9** in order to develop the more efficient synthesis of polysialo ganglio-series gangliosides. We expected that the donor **8** with high reactivity could glycosylate the even the hydroxy group at C-3' of **7**.

Regioselective benzoylation of 2-(trimethylsilyl)ethyl *O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside[13] (**1**) with benzoyl chloride at -50 °C gave the lactose acceptor **2** in 88% yield. Significant signal in ^{1}H NMR spectrum of **2** was one-proton doublet of doublets at δ 5.00 ($J_{2,3}$ 10.6, $J_{3,4}$ 2.7 Hz, H-3b), indicating the assigned structure. Benzylation of methyl 2-deoxy-3,4-*O*-isopropylidene-2-phthalimido-1-thio-β-D-galactopyranoside[18] (**3**) with benzyl bromide and sodium hydride at 0 °C gave the galactosamine donor **4** in 92% yield. Glycosylation of **2** with **4** by use of *N*-iodosuccinimide (NIS)-trifluoromethanesulfonic acid (TfOH) in dichloromethane at -20 °C gave gangliotriose derivative **5** in 53% yield. Significant signal in ^{1}H NMR spectrum of **5** was a one-proton doublet at δ 5.31 ($J_{1,2}$ 8.3 Hz, H-1c), indicating the newly formed glycosidic configuration to be β. De-*O*-benzoylation of **5** with sodium methoxide in methanol at 45 °C gave **6** in 95% yield. Treatment of **6** with hydrazine monohydrate in aqueous 95% ethanol at 75 °C and followed by *N*-acetylation with acetic anhydride in methanol gave the trisaccharide acceptor **7** in high yield. Significant signals in ^{1}H NMR spectrum of **7** were a three-proton singlet at δ 1.79 (AcN), and one-proton doublet at δ 5.67 (NH). Glycosylation[24] of **7** with α-sialyl-(2→8)-sialic acid donor **8** in the presence of NIS-TfOH in acetonitrile at -25 °C gave the pentasaccharide **9** in 50% yield as expected and no β-isomer was isolated. Significant signals in ^{1}H NMR spectrum of **9** were three three-proton singlets at δ 1.80, 1.84 and 1.87 (3 AcN), and two one-proton doublets of doublets at δ 2.26 ($J_{3ax,3eq}$ 13.2, $J_{3eq,4}$ 5.6 Hz H-3e*eq*) and δ 2.71 ($J_{3ax,3eq}$ 13.5, $J_{3eq,4}$ 4.4 Hz, H-3d*eq*), indicating the newly formed glycosidic configuration to be α. De-*O*-isopropylidenation of **9** with aqueous 80% acetic acid afforded the pentasaccharide acceptor **10** in 91% yield.

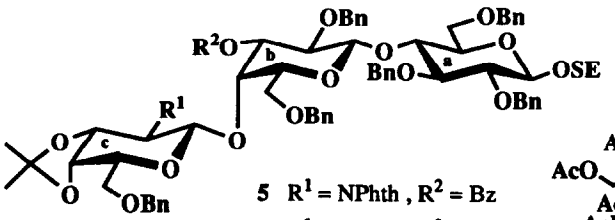
Glycosylation of **10** with methyl thioglycosides of Gal[20] (**18**), Neu5Acα(2→3)Gal[17] (**26**) and Neu5Acα(2→8)Neu5Acα(2→3)Gal[24] (**34**) by use of dimethyl(methylthio)sulfonium triflate (DMTST) in



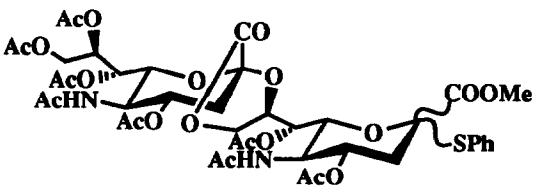
1 R = H
2 R = Bz



3 R = H
4 R = Bn



5 R^1 = NPhth , R^2 = Bz
6 R^1 = NPhth , R^2 = H
7 R^1 = NHAc , R^2 = H



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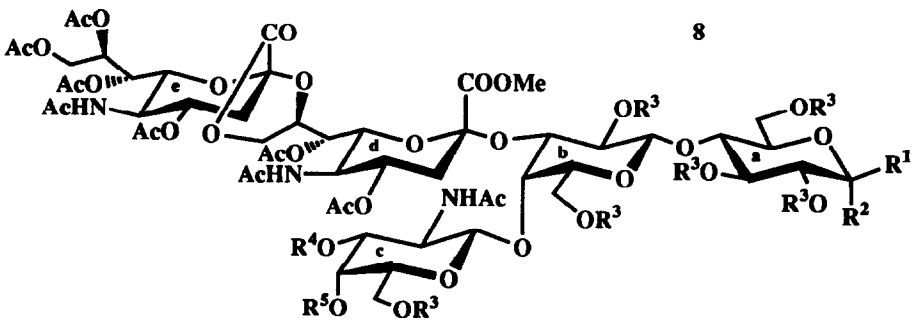
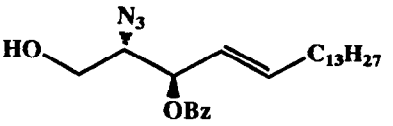


	R^1	R^2	R^3	R^4	R^5
9	OSE	H	Bn	- isopropylidene -	
10	OSE	H	Bn	H	H
11	OSE	H	Ac	Ac	Ac
12	OH , H		Ac	Ac	Ac
13	H	$OC(=NH)CCl_3$	Ac	Ac	Ac

SE = 2-(trimethylsilyl)ethyl
Bn = benzyl
Bz = benzoyl
Phth = phthaloyl



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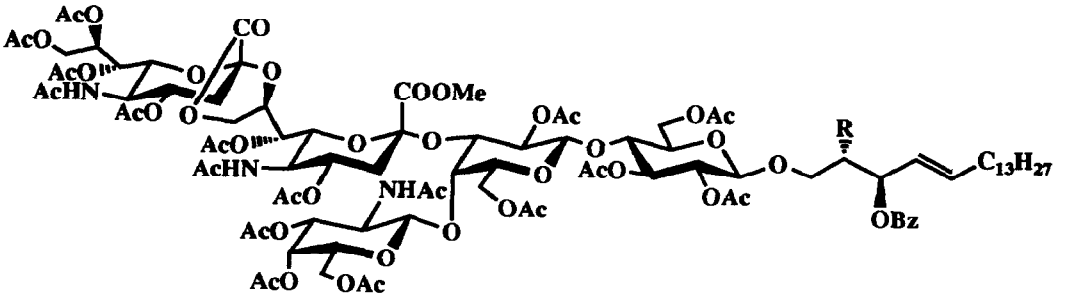
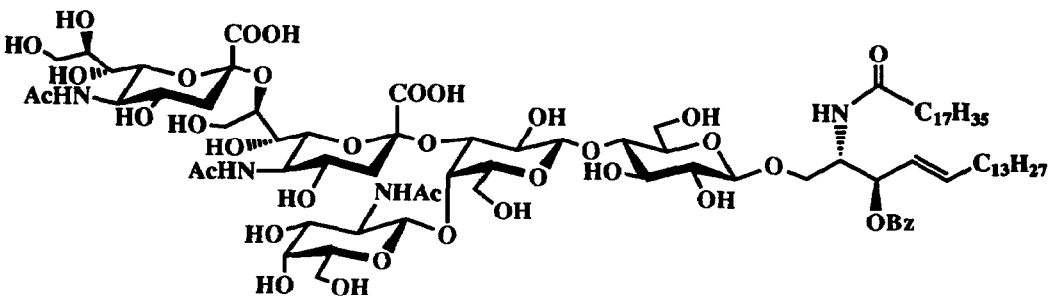
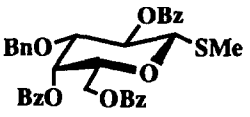


15 R = N_3
16 R = $NHCOC_{17}H_{35}$



17 ganglioside GD2



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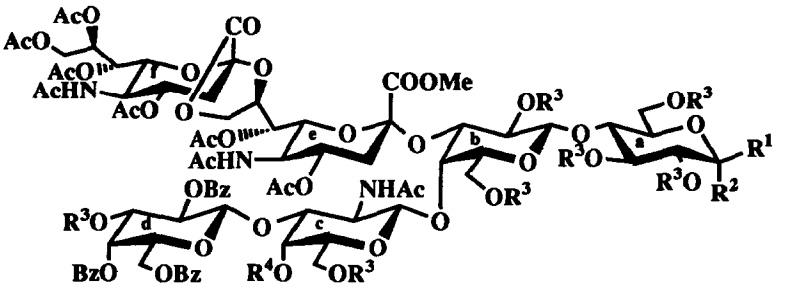
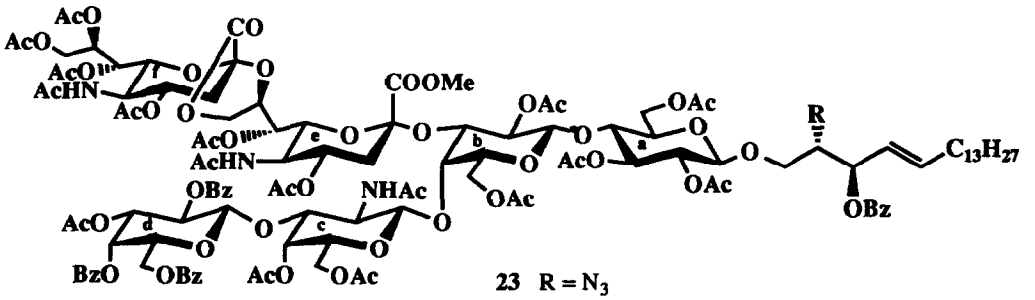
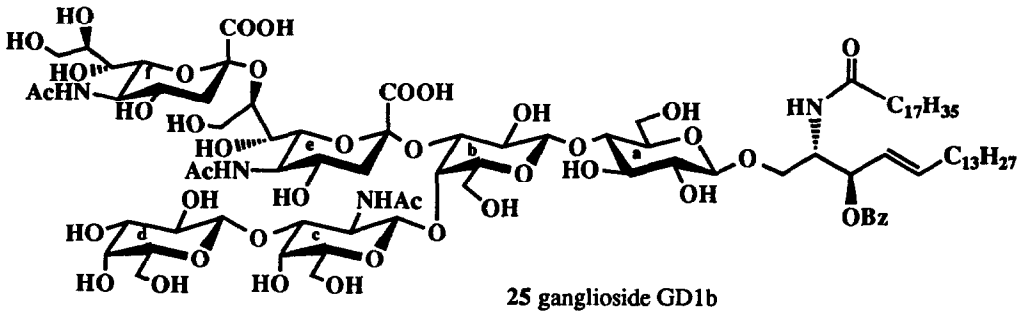


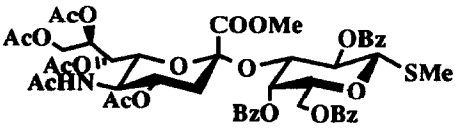
	R^1	R^2	R^3	R^4
19	OSE	H	Bn	H
20	OSE	H	Ac	Ac
21	OH , H		Ac	Ac
22	H	$OC(=NH)CCl_3$	Ac	Ac



23 R = N_3
24 R = $NHCOC_{17}H_{35}$



25 ganglioside GD1b



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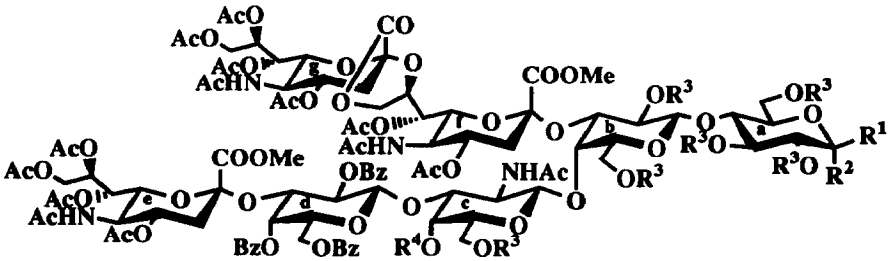
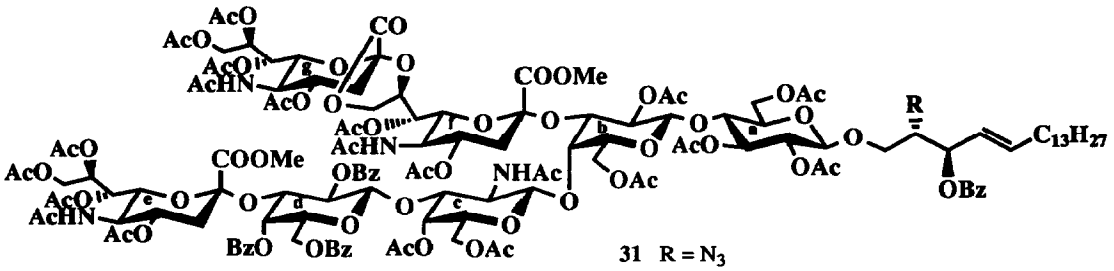
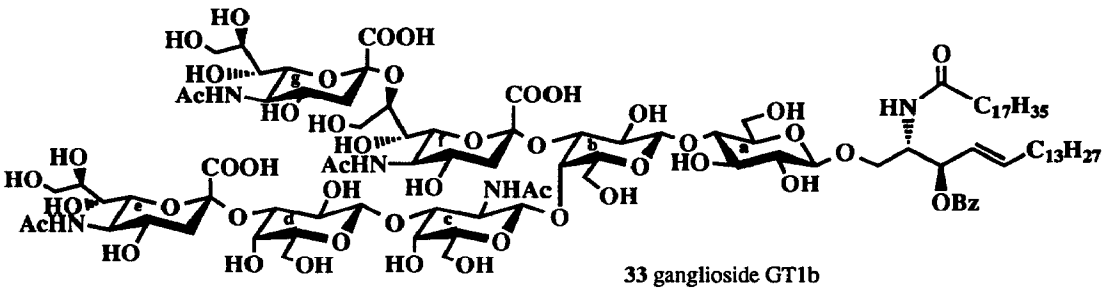


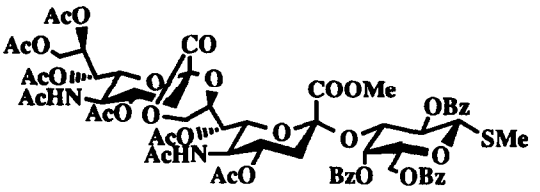
	R^1	R^2	R^3	R^4
27	OSE	H	Bn	H
28	OSE	H	Ac	Ac
29	OH , H		Ac	Ac
30	H	$OC(=NH)CCl_3$	Ac	Ac



31 R = N_3
32 R = $NHCOC_{17}H_{35}$



33 ganglioside GT1b



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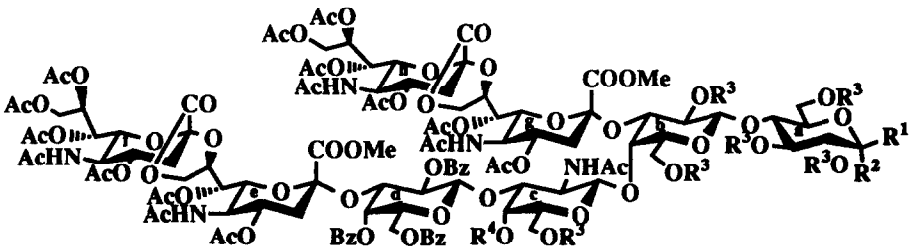
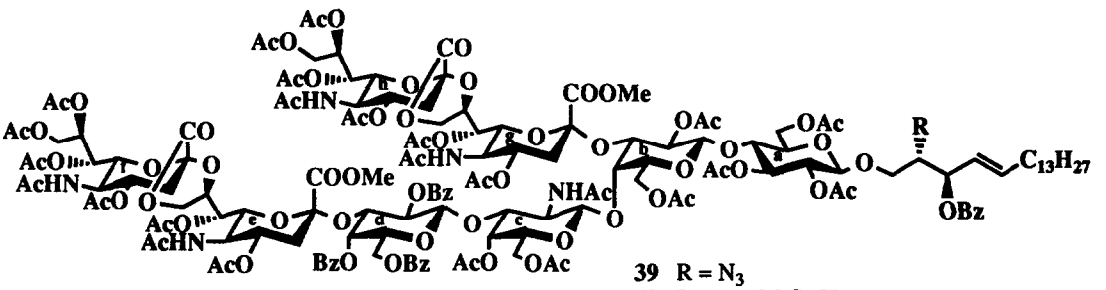
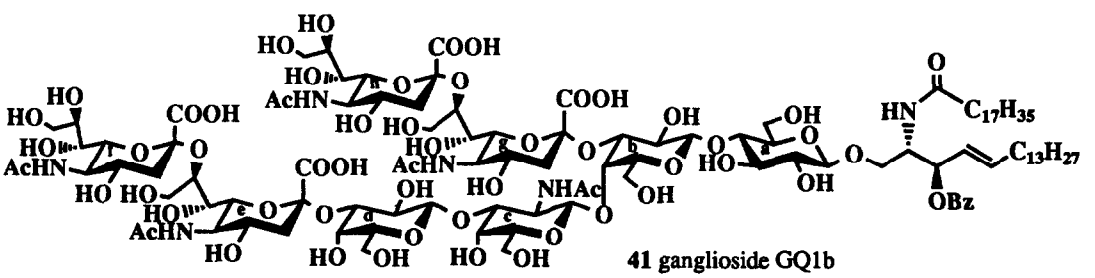


	R^1	R^2	R^3	R^4
35	OSE	H	Bn	H
36	OSE	H	Ac	Ac
37	OH , H		Ac	Ac
38	H	$OC(=NH)CCl_3$	Ac	Ac



39 R = N_3
40 R = $NHCOC_{17}H_{35}$



41 ganglioside GQ1b

dichloromethane gave the corresponding protected ganglioside oligosaccharides **19** (78%), **27** (87%) and **35** (52%), respectively. Reductive removal of benzyl groups in **10**, **19**, **27** and **35** by use of 10% Pd-C, and consequent *O*-acetylation gave the peracylated oligosaccharides **11**, **20**, **28** and **36** (52–93%). Significant signals in ^{1}H NMR spectra of these compounds were one-proton doublets at δ 5.40–5.63 ($J_{3,4}$ 3.4–3.8 Hz, H-4c), indicating the position of glycosylation to be C-3.

Treatment[29] of **11**, **20**, **28** and **36** with trifluoroacetic acid in dichloromethane at room temperature gave the 1-hydroxy compounds **12**, **21**, **29** and **37** (76–94%), which were treated[30] with trichloroacetonitrile in dichloromethane at 0 °C to give the corresponding α-trichloroacetimidates **13**, **22**, **30** and **38** (82–100%). Significant signals in ^{1}H NMR spectra of **13**, **22**, **30** and **38** were a one-proton doublet at δ 6.47–6.48 ($J_{1,2}$ 3.7–4.0 Hz, H-1a) and a one-proton singlet at δ 8.65–8.68 (C=NH) , which showed the imidates to be α.

Glycosylation of (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol[31] (**14**) with **12**, **21**, **29** and **37** was carried out in the presence of trimethylsilyl trifluoromethanesulfonate (TMSOTf) and molecular sieves 4A (AW-300) to give the desired β-glycosides **15**, **23**, **31** and **39** (45–58%), respectively. Selective reduction[32] of azido groups in **15**, **23**, **31** and **39** with H_2S in aqueous 83% pyridine gave the amines, which were treated with octadecanoic acid and 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (WSC) to afford the protected ganglioside derivatives **16**, **24**, **32** and **40** (43–81%), respectively. Finally, *O*-deacylation of these compounds with sodium methoxide in methanol and subsequent saponification of methyl esters and lactone groups gave gangliosides GD2 (**17**), GD1b (**25**), GT1b (**33**) and GQ1b (**41**) in almost quantitative yield. Significant signals in ^{1}H NMR spectra of the synthesized gangliosides were in accordance with those of natural products.

In conclusion, the systematic synthesis of polysialo ganglio-series gangliosides which contain α-sialyl-(2→8)-α-sialic acid residue in their structures was achieved by use of the key glycosyl acceptor **10**. The phenyl 2-thioglycoside derivative of dimeric sialic acid **8** is the useful glycosyl donor for the systematic syntheses of a variety of polysialoglycoconjugates.

EXPERIMENTAL

General Procedures. Optical rotations were determined with a Union PM-201 polarimeter at 25 °C, and IR spectra were recorded with a Jasco IRA-100 spectrophotometer. ^{1}H NMR spectra were recorded at 270 MHz with a Jeol JNM-GX 270 spectrometer and at 500 MHz with a Varian VXR-500S spectrometer, and the NMR data were confirmed by use of decoupling techniques. Preparative chromatography was performed on silica gel (Wako Chemical Co., 200 mesh) with the solvent systems specified. Concentrations were conducted in vacuo.

2-(Trimethylsilyl)ethyl O-*(3-*O*-benzoyl-2,6-di-*O*-benzyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-*D*-glucopyranoside* (**2**). To a solution of 2-(trimethylsilyl)ethyl *O*-(2,6-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside[13] (**1**; 1.0 g, 1.1 mmol) in pyridine (1.5 mL) and CH_2Cl_2 (15 mL) was added benzoyl chloride (0.3 mL, 2.2 mmol), and the solution was stirred for 2 h at -50 °C. Methanol (0.5 mL) was added to the cooled solution, which was then concentrated. The residue was extracted with CH_2Cl_2, washed with 2 M HCl and water, dried (Na_2SO_4), and concentrated. Column chromatography (1:5 EtOAc-hexane) of the syrup on silica gel (30 g) gave **2** (980 mg, 88%) as a syrup; $[\alpha]_D$ +31.7 (*c* 1.0, $CHCl_3$); *v* 3600-3100 (OH), 1730 and 1230 (ester), 860 and 840 (Me_3Si), and 710 and 700 cm^{-1} (Ph); ^{1}H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 4.16 (d, 1 H, $J_{3,4}$ 2.7 Hz, H-4b), 4.35 (d,

1 H, $J_{1,2}$ 7.7 Hz, H-1a), 4.54 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1b), 5.00 (dd, 1 H, $J_{2,3}$ 10.6, $J_{3,4}$ 2.7 Hz, H-3b), and 7.11-7.99 (m, 30 H, 6 Ph). Anal. Calcd for $C_{59}H_{68}O_{12}Si$ (997.27): C, 71.06; H, 6.87. Found: C, 70.84; H, 6.83.

Methyl 6-O-benzyl-2-deoxy-3,4-O-isopropylidene-2-phthalimido-1-thio-β-D-galactopyranoside (**4**). To the solution of methyl 2-deoxy-3,4-*O*-isopropylidene-2-phthalimido-1-thio-β-D-galactopyranoside[18] (**3**; 1.1 g, 2.9 mmol) in *N,N*-dimethylformamide (25 mL) was added NaH (160 mg, 3.9 mmol), and the solution was stirred for 30 min. at 0 °C. To the stirring mixture was added benzyl bromide (0.7 mL, 5.8 mmol), the solution was continuously stirred for 2 h at 0 °C. Methanol (1 mL) was added to the solution and the solution was concentrated. The residue was extracted with CH_2Cl_2, washed with water, dried (Na_2SO_4), and concentrated. Column chromatography (1:2 EtOAc-hexane) of the residue on silica gel (30 g) gave **4** (1.25 g, 92%) as a syrup; $[\alpha]_D$ +37.7 (*c* 1.4, $CHCl_3$); *v* 1700 (imide) and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.35 and 1.64 (2 s, 6 H, Me_2C), 2.15 (s, 3 H, MeS), 3.87 (d, 2 H, $J_{5,6}$ 6.2 Hz, H-6), 4.19 (td, 1 H, $J_{4,5}$ 2.1, $J_{5,6}$ 6.2 Hz, H-5), 4.32 (dd, 1 H, $J_{3,4}$ 4.9, $J_{4,5}$ 2.1 Hz, H-4), 4.38 (dd, 1 H, $J_{1,2}$ 10.5, $J_{2,3}$ 8.9 Hz, H-2), 4.84 (dd, 1 H, $J_{3,4}$ 4.9, $J_{4,5}$ 2.1 Hz, H-4), 4.38 (d, $J_{1,2}$ 10.5 Hz, H-1), and 7.28-7.84 (m, 9 H, 2 Ph). Anal. Calcd for $C_{25}H_{27}NO_6S$ (469.56): C, 63.95; H, 5.80; N, 2.98. Found: C, 63.92; H, 5.66; N, 2.75.

2-(Trimethylsilyl)ethyl O-(6-O-benzyl-2-deoxy-3,4-O-isopropylidene-2-phthalimido-β-D-galactopyranosyl) -(1→4) -O-(3-O-benzoyl-2,6 -di-O-benzyl- β-D-galactopyranosyl) - (1→4)- 2,3,6 -tri-O-benzyl-β-D-glucopyranoside (**5**). To a solution of **2** (2.5 g, 2.5 mmol) and **4** (1.4 g, 3.0 mmol) in CH_2Cl_2 (15 mL) were added molecular sieves 4A (3.0 g), and the mixture was stirred for 5 h at room temperature, then cooled to -30 °C. To the cooled mixture were added *N*-iodosuccinimide (NIS; 1.7 g, 7.5 mmol) and trifluoromethanesulfonic acid (TfOH; 60 μL, 0.7 mmol), and the stirring was continued for 3 h at -30 °C. The solids were filtered off, and washed with CH_2Cl_2. The combined filtrate and washings was washed with M Na_2CO_3 and M $Na_2S_2O_3$, dried (Na_2SO_4), and concentrated. Column chromatography (1:5 EtOAc-hexane) of the residue on silica gel (100g) gave **5** (1.9 g, 53%) as an amorphous mass; $[\alpha]_D$ +30.0 (*c* 1.0, $CHCl_3$); *v* 1730 and 1230 (ester), 1700 (imide), 860 and 840 (Me_3Si), and 710 and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.32 and 1.60 (2 s, 6 H, Me_2C), 3.54 and 4.00 (2 m, 2 H, $Me_3SiCH_2CH_2$), 4.33 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1a), 4.37 (dd, 1 H, $J_{1,2}$ 8.3, $J_{2,3}$ 9.3 Hz, H-2c), 4.46 (d, 1 H, $J_{1,2}$ 7.7 Hz, H-1b), 4.87 (dd, 1 H, $J_{2,3}$ 9.3, $J_{3,4}$ 5.0 Hz, H-3c), 4.90 (dd, 1 H, $J_{2,3}$ 10.1 $J_{3,4}$ 2.5 Hz, H-3b), 5.31 (d, 1 H, $J_{1,2}$ 8.3 Hz, H-1c), and 6.91-8.02 (m, 39 H, 8 Ph). Anal. Calcd for $C_{83}H_{91}NO_{18}Si$ (1418.72): C, 70.27; H, 6.47; N, 0.99. Found: C, 70.25; H, 6.30; N, 0.95.

2-(Trimethylsilyl)ethyl O-(6-O-benzyl-2-deoxy-3,4-O-isopropylidene-2-phthalimido-β-D-galactopyranosyl)-(1→4)-O-(2,6-di-O-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-benzyl-β-D-glucopyranoside (**6**). To a solution of **5** (0.6 g, 0.42 mmol) in MeOH (15 mL) was added MeONa (catalyst), and the solution was stirred for 1 day at 45 °C. The solution was neutralized with Amberlite IR-120 (H^+), filtered, and concentrated. Column chromatography (1:3 EtOAc-hexane) of the residue on silica gel (20 g) gave **6** (0.53 g, 95%) as an amorphous mass; $[\alpha]_D$ +8.4 (*c* 1.0, $CHCl_3$); *v* 1700 (imide), 860 and 840 (Me_3Si), and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.33 and 1.56 (2 s, 6 H, Me_2C), 5.24 (d, 1 H, $J_{1,2}$ 8.6 Hz, H-1c), and 6.91-7.80 (m, 34 H, 7 Ph). Anal. Calcd for $C_{76}H_{87}NO_{17}Si$ (1314.61): C, 69.44; H, 6.67; N, 1.07. Found: C, 69.36; H, 6.52; N, 0.94.

2-(Trimethylsilyl)ethyl O-(2-acetamido-6-O-benzyl-2-deoxy-3,4-O-isopropylidene-β-D-galactopyranosyl)-(1→4)-O-(2,6-di-O-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-benzyl-β-D-glucopyranoside (**7**). To a

solution of **6** (130 mg, 0.1 mmol) in aq. 95% EtOH (5 mL) was added hydrazine monohydrate (80 μL, 1.6 mmol), and the solution was stirred for 6 h at 75 °C. The solids were filtered off, washed with EtOH, and the combined filtrate and washings was concentrated to a syrup. To a solution of the residue in MeOH (1.0 mL) was added Ac_2O (25 μL, 0.2 mmol), and the solution was stirred for 1 h at room temperature. Pyridine (0.1 mL) was added to the solution, and evaporated. The syrup was extracted with CH_2Cl_2, and washed with M Na_2CO_3 and water, dried (Na_2SO_4), and concentrated. Column chromatography (1:2 EtOAc-hexane) of the syrup on silica gel (10 g) gave **7** (120 mg, quantitative) as an amorphous mass; $[\alpha]_D$ +15.2 (*c* 0.8, $CHCl_3$); *v* 3600-3100 (OH, NH), 1650 and 1540 (amide), 860 and 840 (Me_3Si), and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.30 and 1.50 (2 s, 6 H, Me_2C), 1.79 (s, 3 H, AcN), 5.24 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1c), 5.67 (d, 1 H, $J_{5,NH}$ 9.0 Hz, NH), and 7.18-7.80 (m, 30 H, 6 Ph). Anal. Calcd for $C_{70}H_{87}NO_{16}Si$ (1226.54): C, 68.55; H, 7.15; N, 1.14. Found: C, 68.51; H, 6.99; N, 0.88.

2-(Trimethylsilyl)ethyl O-*[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)-[*O*-(2-acetamido-6-*O*-benzyl-2-deoxy-3,4-*O*-isopropylidene-β-D-galactopyranosyl)-(1→4)]-*O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside* (**9**). To a solution of **7** (1.0 g, 0.82 mmol) and methyl [phenyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto* -2-nonulopyranosylono-1',9-lactone)-4,7-di-*O* -acetyl- 3,5-dideoxy-2-thio-D-*glycero*-D-*galacto*-2-nonulopyranosid]onate[24] (**8**; 1.5 g, 1.6 mmol) in MeCN (5 mL) were added molecular sieves 3A (1.1g), the mixture was stirred for 5 h at room temperature, then cooled to -25 °C. To the cooled mixture were added NIS (750 mg, 3.2 mmol) and TfOH (30 μL, 0.3 mmol), and the stirring was continued for 1 day at -25 °C. The solids were filtered off, and washed with CH_2Cl_2. The combined filtrate and washings with M Na_2CO_3 and M $Na_2S_2O_3$, dried (Na_2SO_4), and concentrated. The syrup was extracted with CH_2Cl_2, washed with 2 M HCl and M Na_2CO_3, dried (Na_2SO_4), and concentrated. Column chromatography (80:1 CH_2Cl_2-MeOH) of the residue on silica gel (50 g) gave **9** (835 mg, 50%) as an amorphous mass; $[\alpha]_D$ -31.4 (*c* 0.7, $CHCl_3$); *v* 3300 (NH), 1730 and 1230 (ester), 1650 and 1540 (amide), 860 and 840 (Me_3Si), and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 500 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.35 and 1.50 (2 s, 6 H, Me_2C), 1.80, 1.84 and 1.87 (3 s, 9 H, 3 AcN), 1.97-2.19 (6 s, 18 H, 6 AcO), 2.26 (dd, 1 H, $J_{3ax,3eq}$ 13.2, $J_{3eq,4}$ 5.6 Hz, H-3c*eq*), 2.71 (dd, 1 H, $J_{3ax,3eq}$ 13.5, $J_{3eq,4}$ 4.4 Hz, H-3d*eq*), 3.09 (m, 1 H, H-2c), 3.40 (s, 3 H, MeO), 3.60 and 4.01 (2 m, 2 H, $Me_3SiCH_2CH_2$), 3.70 (q, 1 H, $J_{4,5} = J_{5,6} = J_{5,NH}$ = 9.3 Hz, H-5d), 4.11 (q, 1 H, $J_{4,5} = J_{5,6} = J_{5,NH}$ = 10.2 Hz, H-5e), 4.32 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1a), 4.46 (d, 1 H, $J_{1,2}$ 7.3 Hz, H-1b), 5.02 (m, 1 H, H-8e), 5.31 (dd, 1 H, $J_{6,7}$ 1.7, $J_{7,8}$ 10.0 Hz, H-7e), 5.40 (m, 2 H, H-1c and H-4e), 5.50 (m, 1 H, H-4d), 5.68 (d, 1 H, $J_{2,NH}$ 8.1 Hz, NHc), 6.43 (d, 1 H, $J_{5,NH}$ 9.3 Hz, NHd), and 7.21-7.35 (m, 30 H, 6 Ph). Anal. Calcd for $C_{105}H_{133}N_3O_{37}Si$ (2057.29): C, 61.30; H, 6.52; N, 2.04. Found: C, 61.12; H, 6.34; N, 1.85.

2-(Trimethylsilyl)ethyl O-*[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonuropyranosylonate]-(2→3)-[*O*-(2-acetamido-6-*O*-benzyl-2-deoxy-β-D-galactopyranosyl)-(1→4)]-*O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside* (**10**). A solution of **9** (150 mg, 0.07 mmol) in aq. 80% AcOH (5 mL) was kept for 3 h at 60 °C, and concentrated. Column chromatography (50:1 CH_2Cl_2-MeOH) of the residue on silica gel (10 g) gave **10** (134 mg, 91%) as an amorphous mass; $[\alpha]_D$ -31.0° (*c* 1.2, $CHCl_3$); *v* 3600-3100 (OH, NH), 1730 and 1230 (ester), 1650 and 1540

(amide), 860 and 840 (Me_3Si), and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.83-2.17 (9 s, 27 H, 3 AcN and 6 AcO), 2.63 (dd, 1 H, $J_{3ax,3eq}$ 13.3, $J_{3eq,4}$ 3.5 Hz, H-3d*eq*), 3.42 (s, 3 H, MeO), 5.03 (m, 1 H, H-8e), 5.29 (dd, 1 H, $J_{6,7}$ 1.6, $J_{7,8}$ 10.0, H-7e), and 7.13-7.38 (m, 30 H, 6 Ph). Anal. Calcd for $C_{102}H_{129}N_3O_{37}Si$ (2017.09): C, 60.73; H, 6.45; N, 2.08. Found: C, 60.49; H, 6.31; N, 1.89.

2-(Trimethylsilyl)ethyl O-*[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-2-nonulopyranosylonate]-(2→3)-[*O*-(2-acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)]-*O*-(2,6-di-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-β-*D*-glucopyranoside* (**11**). A solution of **10** (300 mg, 0.15 mmol) in EtOH (6 mL) and AcOH (3 mL) was hydrogenolyzed in the presence of 10% Pd-C (300 mg) for 2 days at 45 °C. The solids were filtered off and washed with MeOH. The combined filtrate and washings was concentrated, and a solution of the residue in Ac_2O (2 mL) and pyridine (4 mL) was stirred for 12 h at 45 °C, and concentrated. Column chromatography (20:1 CH_2Cl_2-MeOH) of the residue on silica gel (10 g) gave **11** (134 mg, 91%) as an amorphous mass; $[\alpha]_D$ -26.4 (*c* 1.6, $CHCl_3$); *ν* 3300 (NH), 1730 and 1230 (ester), 1650 and 1540 (amide), and 860 and 840 cm^{-1} (Me_3Si); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.88-2.26 (17 s, 51 H, 3 AcN and 14 AcO), 2.56 (m, 2 H, H-3d*eq* and H-3e*eq*), 3.47 (s, 3 H, MeO), 3.57 and 3.95 (2 m, 2 H, $Me_3SiCH_2CH_2$), 4.22 (d, 1 H, $J_{1,2}$ 7.1 Hz, H-1a), and 4.48 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1b). Anal. Calcd for $C_{76}H_{109}N_3O_{45}Si$ (1812.77): C, 50.36; H, 6.06; N, 2.32. Found: C, 50.31; H, 6.01; N, 2.02.

*O-[Methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-2-nonulopyranosylonate]-(2→3)-[*O*-(2-acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)]-*O*-(2,6-di-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-*D*-glucopyranose* (**12**). A solution of **11** (80 mg, 0.044 mmol) in trifluoroacetic acid (0.2 mL) and CH_2Cl_2 (0.5 mL) was stirred for 2 h at room temperature. Ethyl acetate (1 mL) was added to the stirring solution, and evaporated. Column chromatography (15:1 CH_2Cl_2-MeOH) of the syrup on silica gel (10 g) gave **12** (70 mg, 93%) as an amorphous mass; *ν* 3300 (NH), 1730 and 1230 (ester), and 1650 and 1540 cm^{-1} (amide). Anal. Calcd for $C_{71}H_{97}N_3O_{45}$ (1712.53): C, 49.80; H, 5.71; N, 2.45. Found: C, 49.50; H, 5.59; N, 2.16.

*O-[Methyl 5 acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-2-nonulopyranosylono-1', 9 -lactone)-4, 7 -di-*O*-acetyl- 3,5 -dideoxy-*D*-glycero-α-*D*-galacto-2 -nonulopyranosylonate]- (2→3) -[O- (2-acetamido-3,4,6-tri-*O*-acetyl- 2-deoxy-β-*D*-galactopyranosyl)-(1→4)] -O-(2,6-di-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-α-*D*-glucopyranosyl trichloroacetimidate* (**13**). To a solution of **12** (70 mg, 0.04 mmol) in trichloroacetonitrile (0.2 mL) and CH_2Cl_2 (1.0 mL) was added 1,8-diazabicyclo[5.4.0]undec-7-ene (6 μL, 0.042 mmol), and the mixture was stirred for 30 min. at 0 °C. Column chromatography (30:1 CH_2Cl_2-MeOH) of the solution on silica gel (10 g) gave **13** (75 mg, quantitative) as an amorphous mass; $[\alpha]_D$ -5.0 (*c* 0.7, $CHCl_3$); *ν* 3300 (NH), 1730 and 1230 (ester), and 1650 and 1540 cm^{-1} (amide); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.87-2.35 (17 s, 51 H, 3 AcN and 14 AcO), 2.54 (m, 2 H, H-3d*eq* and H-3e*eq*), 3.47 (s, 3 H, MeO), 6,48 (d, 1 H, $J_{1,2}$ 4.0 Hz, H-1a), and 8.66 (s, 1 H, C=NH). Anal. Calcd for $C_{73}H_{97}Cl_3N_4O_{45}$ (1856.92): C, 47.22; H, 5.27; N, 3.02. Found: C, 47.11; H, 5.15; N, 2.77.

*O-[Methyl 5 acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-2-nonulopyranosylono-1',9- lactone)-4,7 -di-O- acetyl-3 ,5 -dideoxy-*D*-glycero-α-*D*- galacto-2 -nonulopyranosylonate]-(2→3)-[O-(2-acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)]- O-(2,6-di-O-acetyl-*

β-D-*galactopyranosyl)-(1→4)*-O *-(2,3,6- tri*-O *-acetyl-β*-D *-glucopyranosyl)-(1→1)-(2S,3R,4E)-2-azido-3*-O-*benzoyl-4-octadecene-1,3-diol* (**15**). To a solution of **13** (44 mg, 0.024 mmol) and (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol[31b] (**14**; 20 mg, 0.05 mmol) in CH_2Cl_2 (0.4 mL) were added molecular sieves 4A (AW-300; 500 mg), and the mixture was stirred for 5 h at room temperature, then cooled 0 °C. To the cooled mixture was added trimethylsilyl trifluoromethanesulfonate (10 μL, 0.05 mmol), the stirring was continued for 12 h at 0 °C. The solids were filtered off, and washed with CH_2Cl_2. The combined filtrate and washings was washed with M Na_2CO_3 and water, dried (Na_2SO_4), and concentrated. Column chromatography (20:1 CH_2Cl_2-MeOH) of the residue on silica gel (10 g) gave **15** (26 mg, 56%) as amorphous mass; $[\alpha]_D$ -23.0 (*c* 0.5, $CHCl_3$); *ν* 3300 (NH), 2200 (azide), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 0.88 (t, 3 H, $J_{Me,CH2}$ 6.8 Hz, *Me*CH_2), 1.24 (s, 22 H, 11 CH_2), 1.90-2.22 (17 s, 51 H, 3 AcN and 14 AcO), 2.54 (m, 2 H, H-3d*eq* and H-3e*eq*), 3.47 (s, 3 H, MeO), 4.96 (m, 1 H, H-4d), 5.93 (dt, 1 H, $J_{4,5}$ 12.0, $J_{5,6} = J_{5,6'}$ = 6.6 Hz, H-5 of sphingosine), and 7.33-8.14 (m, 5 H, Ph). Anal. Calcd for $C_{96}H_{134}N_6O_{47}$ (2124.12): C, 54.28; H, 6.36; N, 3.96. Found: C, 54.28; H, 6.31; N, 3.71.

O-*[Methyl 5-acetamido-8*-O-*(5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy*-D-glycero-*α*-D-galacto-*2-nonulopyranosylono-1',9-lactone) -4,7-di*-O *-acetyl -3,5-dideoxy*-D -glycero-*α* -D -galacto-*2 -nonulopyranosylonate]-(2→3)- [*O-*(2-acetamido-3,4,6-tri*-O-*acetyl-2-deoxy-β*-D-*galactopyranosyl)-(1→4)]*-O-*(2,6-di*-O-*acetyl-β*-D-*galactopyranosyl)-(1→4)*-O- *(2,3,6-tri*-O-*acetyl-β*-D-*glucopyranosyl)- (1→1)- (2S,3R,4E)-3*-O-*benzoyl-2-octadecanamido-4-octadecene-1,3-diol* (**16**). Hydrogen sulfide was bubbled into a solution of **15** (26 mg, 0.013 mmol) in aq. 83% pyridine (2.4 mL) for 3 days at 0 °C, and the solution was evaporated. To a solution of the residue in CH_2Cl_2 (1.0 mL) were added octadecanoic acid (11 mg, 0.04 mmol) and 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (WSC; 8 mg, 0.04 mmol). The mixture was stirred for 12 h at room temperature, washed with water, dried (Na_2SO_4), and concentrated. Column chromatography (25:1 CH_2Cl_2-MeOH) of the residue on silica gel (10 g) gave **16** (20 mg, 69%) as amorphous mass; $[\alpha]_D$ -12.0 (*c* 0.4, $CHCl_3$); *ν* 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 0.88 (t, 6 H, $J_{Me,CH2}$ 6.8 Hz, 2 *Me*CH_2), 1.24 (s, 52 H, 26 CH_2), 1.90-2.22 (17 s, 51 H, 3 AcN and 14 AcO), 2.52 (m, 2 H, H-3d*eq* and H-3e*eq*), 3.48 (s, 3 H, MeO), 5.83 (m, 1 H, H-5 of ceramide), and 7.32-8.10 (m, 5 H, Ph). Anal. Calcd for $C_{114}H_{170}N_4O_{48}$ (2364.59): C, 57.91; H, 7.25; N, 2.37. Found: C, 57.85; H, 7.25; N, 2.19.

Ganglioside GD2 (**17**). To a solution of **16** (20 mg, 8.5 μmol) in MeOH (5 mL) was added MeONa (catalyst), and the mixture was stirred for 2 days at 40 °C. To the mixture was added 0.2 M KOH (0.5 mL), the stirring was continued for 1 day at 40 °C. The solution was neutralized with Amberlite IR-120 (H^+), filtered, and concentrated. Column chromatography (5:5:1 $CHCl_3$-MeOH-H_2O) of the residue on Sephadex LH-20 gel gave **17** (14 mg, quantitative); $[\alpha]_D$ -7.1 (*c* 0.4, 5:5:1 $CHCl_3$-MeOH-H_2O); ^1H NMR [20:1 $(CD_3)_2SO$-D_2O] at 270 MHz: δ 0.88 (t, 6 H, $J_{Me,CH2}$ 6.8 Hz, 2 *Me*CH_2), 1.25 (s, 52 H, 26 CH_2), 1.87-1.96 (3 s, 9 H, 3 AcN), 2.26 (t, 2 H, $J_{CH2,CH2}$ 6.8 Hz, COC*H2*CH2), 2.60-2.80 (m, 2 H, H-3d*eq* and H-3e*eq*), and 5.41 (m, 1 H, H-5 of ceramide). Anal. Calcd for $C_{78}H_{138}N_4O_{34}$ (1675.96): C, 55.90; H, 8.30; N, 3.34. Found: C, 55.85; H, 8.05; N, 3.32.

2-(Trimethylsilyl)ethyl O-*(2,4,6-tri*-O-*benzoyl-3*-O-*benzyl-β*-D-*galactopyranosyl)-(1→3)*-O-*(2-acetamido-6*-O-*benzyl-2-deoxy-β*-D-*galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8*-O-*(5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy*-D-glycero-*α*-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di*-O-*acetyl-3,5-dideoxy*-D-

glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)}*-O-*(2,6-di*-O-*benzyl-β*-D-*galactopyranosyl)-(1→4)-2,3,6-tri*-O-*benzyl-β*-D-*glucopyranoside* (**19**). To a solution of **10** (200 mg, 0.10 mmol) and methyl 2,4,6-tri-*O*-benzoyl-3-*O*-benzyl-1-thio-β-D-galactopyranoside[18] (**18**, 73 mg, 0.12 mmol) in CH_2Cl_2 (4 mL) were added molecular sieves 4A (800 mg), and the mixture was stirred for 5 h at room temperature, then cooled to -10 °C. To the cooled mixture was added dimethyl(methylthio)sulfonium triflate (DMTST; 65 mg, 0.24 mmol), and the stirring was continued for 8 h at -10 °C. The solids were filtered off, and washed with CH_2Cl_2. The combined filtrate and washings was washed with M Na_2CO_3 and water, dried (Na_2SO_4), and concentrated. Column chromatography (50:1 CH_2Cl_2-MeOH) of the syrup on silica gel (20 g) gave **19** (200 mg, 78%) as an amorphous mass; $[\alpha]_D$ -6.5° (*c* 1.2, $CHCl_3$); *ν* 3600-3100 (OH, NH), 1750 and 1230 (ester), 1650 and 1540 (amide), 860 and 840 (Me_3Si), and 710 and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.75-2.14 (9 s, 27 H, 3 AcN and 6 AcO), 2.34 (dd, 1 H, $J_{3ax,3eq}$ 13.7, $J_{3eq,4}$ 6.8 Hz, H-3f*eq*), 2.64 (dd, 1H, $J_{3ax,3eq}$ 13.3, $J_{3eq,4}$ 4.6 Hz, H-3e*eq*), 3.44 (s, 3 H, MeO), 5.13 (m, 1 H, H-4e), 5.34 (dd, 1 H, $J_{6,7}$ 2.2, $J_{7,8}$ 10.1 Hz, H-7f), 5.39 (m, 1 H, H-4f), and 7.01-8.19 (m, 50 H, 10 Ph). Anal. Calcd for $C_{136}H_{157}N_3O_{45}Si$ (2581.81): C, 63.27; H, 6.13; N, 1.63. Found: C, 63.02; H, 6.09; N, 1.55.

2-(Trimethylsilyl)ethyl O-*(3-O-acetyl-2,4,6-tri-O-benzoyl-β-D-galactopyranosyl)-(1→3)-O-(2-acetamido-4,6-di-O-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-O-(5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-2-nonulopyranosylonate]-(2→3)}-O-(2,6-di-O-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-β-D-glucopyranoside* (**20**). Removal of benzyl groups and subsequent *O*-acetylation of **19** (320 mg, 0.12 mmol), as described for **11**, gave **20** (270 mg, 93%) as an amorphous mass; $[\alpha]_D$ -23.1 (*c* 1.1, $CHCl_3$); *ν* 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), 860 and 840 (Me_3Si), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.85-2.21 (17 s, 51 H, 3 AcN and 14 AcO), 2.55 (m, 2 H, H-3e*eq* and H-3f*eq*), 3.46 (s, 3 H, MeO), 5.63 (d, 1 H, $J_{3,4}$ 3.8 Hz, H-4c), 5.85 (d, 1 H, $J_{3,4}$ 2.8 Hz, H-4d), and 7.30-8.25 (m, 15 H, 3 Ph). Anal. Calcd for $C_{103}H_{131}N_3O_{53}Si$ (2287.24): C, 54.09; H, 5.77; N, 1.84. Found: C, 54.07; H, 5.69; N, 1.67.

O-*(3-O-Acetyl-2,4,6-tri-O-benzoyl-β-D-galactopyranosyl)-(1→3)-O-(2-acetamido-4,6-di-O-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-O-(5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-2-nonulopyranosylonate]-(2→3)}-O-(2,6-di-O-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-D-glucopyranose* (**21**). Removal of 2-(trimethylsilyl)ethyl group of **21** (260 mg, 0.11 mmol), as described for **12**, gave **21** (190 mg, 76%) as an amorphous mass; *ν* 3600-3100 (OH, NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph). Anal. Calcd for $C_{98}H_{119}N_3O_{53}$ (2187.00): C, 53.82; H, 5.48; N, 1.92. Found: C, 53.69; H, 5.20; N, 1.73.

O-*(3-O-Acetyl-2,4,6-tri-O-benzoyl-β-D-galactopyranosyl)-(1→3)-O-(2-acetamido-4,6-di-O-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-O-(5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-2-nonulopyranosylonate]-(2→3)}-O-(2,6-di-O-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-α-D-glucopyranosyl trichloroacetimidate* (**22**). Treatment of **21** (190 mg, 0.09 mmol), as described for **13**, gave **22** (166 mg, 82%) as an amorphous mass; $[\alpha]_D$ 0.0 (*c* 0.7 $CHCl_3$), ν 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.86-2.12 (17 s, 51 H, 3 AcN and 14 AcO), 2.61 (m, 2 H, H-3e*eq* and H-3f*eq*), 3.47 (s, 3 H, MeO), 5.63 (d, 1 H, $J_{3,4}$ 3.5 Hz,

H-4c), 5.82 (d, 1 H, $J_{3,4}$ 3.5 Hz, H-4d), 6.47 (d, 1 H, $J_{1,2}$ 3.8 Hz, H-1a), 7.39-8.20 (m, 15 H, 3 Ph), and 8.65 (s, 1 H, C=NH). Anal. Calcd for $C_{100}H_{119}Cl_3N_4O_{53}$ (2331.39): C, 51.52; H, 5.15; N, 2.40. Found: C, 51.35; H, 4.99; N, 2.36.

O -*(3-O -Acetyl-2,4,6-tri-O -benzoyl-β -D -galactopyranosyl)-(1→3) -O -(2-acetamido-4,6-di-O -acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-O-(5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-*D-glycero-*α-D-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-2-nonulopyranosylonate]-(2→3)}-O-(2,6-di-O-acetyl-β -D-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-acetyl-β-D-glucopyranosyl)-(1→1)-(2S,3R,4E)-2-azido-3-O-benzoyl-4-octadecene-1,3-diol* (**23**). Condensation of **22** (170 mg, 0.07 mmol) with **14** (60 mg, 0.14 mmol), as described for **15**, gave **23** (80 mg, 45%) as an amorphous mass; $[\alpha]_D$ -20.3 (*c* 0.8, $CHCl_3$); *ν* 3300 (NH), 2200 (azide), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 0.88 (t, 3 H, $J_{Me,CH2}$ 6.8 Hz, *Me*CH_2), 1.24 (s, 22 H, 11 CH_2), 1.85-2.19 (17 s, 51 H, 3 AcN and 14 AcO), 2.62 (m, 2 H, H-3e*eq* and H-3f*eq*), 3.45 (s, 3 H, MeO), 5.81 (d, 1 H, $J_{3,4}$ 3.6 Hz, H-4d), 5.95 (m, 1 H, H-5 of sphingosine), and 7.31-8.25 (m, 20 H, 4 Ph). Anal. Calcd for $C_{123}H_{156}N_6O_{55}$ (2598.59): C, 56.85; H, 6.05; N, 3.23. Found: C, 56.82; H, 5.87; N, 3.08.

O -*(3-O -Acetyl-2,4,6-tri-O -benzoyl-β -D -galactopyranosyl)-(1→3) -O -(2-acetamido-4,6-di-O -acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-O-(5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-*D-glycero-*α-D-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-2-nonulopyranosylonate]-(2→3)}-O -(2,6-di-O -acetyl-β-D-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-acetyl-β-D-glucopyranosyl)-(1→1)-(2S,3R,4E)-3-O-benzoyl-2-octadecanamido-4-octadecene-1,3-diol* (**24**). Treatment of **23** (80 mg, 0.03 mmol), as described for **16**, gave **24** (71 mg, 81%) as an amorphous mass; $[\alpha]_D$ -13.8 (*c* 1.4, $CHCl_3$); *ν* 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 0.88 (t, 6 H, $J_{Me,CH2}$ 6.9 Hz, 2 *Me*CH_2), 1.25 (s, 52 H, 26 CH_2), 1.85-2.19 (17 s, 51 H, 3 AcN and 14 AcO), 2.61 (m, 2 H, H-3e*eq* and H-3f*eq*), 3.45 (s, 3 H, MeO), 5.81 (m, 2 H, H-4d and H-5 of ceramide), and 7.40-8.20 (m, 20 H, 4 Ph). Anal. Calcd for $C_{141}H_{192}N_4O_{56}$ (2839.06): C, 59.65; H, 6,82; N, 1.97. Found: C, 59.48; H, 6.76; N, 1.70.

Ganglioside GD1b (**25**). De-*O*-acylation and saponification of methyl ester and lactone group in **24** (70 mg, 0.025 mmol), as described for **17**, gave **25** (45 mg, quantitative); $[\alpha]_D$ -1.2 (*c* 0.5, 5:5:1 $CHCl_3$-MeOH-H_2O); ^1H NMR [$(CD_3)_2SO$-D_2O] at 270 MHz: δ 0.88 (t, 6 H, $J_{Me,CH2}$ 6.8 Hz, 2 *Me*CH_2), 1.24 (s, 52 H, 26 CH_2), 1.81 and 1.92 (2 s, 9 H, 3 AcN), 2.66 and 2.81 (2 m, 2 H, H-3e*eq* and H-3f*eq*), 4.16 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1a), 4.35 (m, 2 H, H-1b and H-1d), 4.80 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1c), 5.38 (dd, 1 H, $J_{3,4}$ 7.6, $J_{4,5}$ 14.3 Hz, H-4 of ceramide), 5.59 (m, 1 H, H-5 of ceramide). Anal. Calcd for $C_{84}H_{148}N_4O_{39}$ (1838.10): C, 54.89; H, 8.12; N, 3.05. Found: C, 54.87; H, 7.92; N, 2.86.

*2-(Trimethylsilyl)ethyl O-(methyl 5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-O -(2,4,6-tri-O -benzoyl-β -D-galactopyranosyl)-(1→3)-O -(2-acetamido-6-O-benzyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-O-(5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-O-acetyl-3,5-dideoxy-D-glycero-α -D -galacto-2-nonulopyranosylonate]-(2→3)} -O -(2,6-di-O -benzyl-β -D -galactopyranosyl)-(1→4)-2,3,6-tri-O-benzyl-β-D-glucopyranoside* (**27**). Glycosylation of **10** (300 mg, 0.15 mmol) with methyl *O*-(methyl 5-acetamido-4,7,8,9 -tetra-*O*-acetyl-3,5 -dideoxy-D-*glycero* -α-D-*galacto*-2- nonulopyranosylonate)-(2→3)-2,4,6-tri-*O*-benzoyl-1-thio-β-D-galactopyranoside[17] (**26**; 220 mg, 0.23 mmol), as described for **19**,

gave **27** (382 mg, 87%) as an amorphous mass; $[\alpha]_D$ -12.0 (*c* 1.0, $CHCl_3$); *v* 3600-3100 (OH, NH), 1750 and 1230 (ester), 1650 and 1540 (amide), 860 and 840 (Me_3Si), and 710 and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.86-2.17 (14 s, 42 H, 4 AcN and 10 AcO), 2.43 (dd, 1 H, $J_{3ax,3eq}$ 13.2, $J_{3eq,4}$ 4.3 Hz, H-3e*eq*), 2.64 (dd, 1 H, $J_{3ax,3eq}$ 13.5, $J_{3eq,4}$ 4.3 Hz, H-3fe*q*), 3.45 and 3.70 (2 s, 6 H, 2 MeO), and 7.28-8.18 (m, 15 H, 3 Ph). Anal. Calcd for $C_{149}H_{178}N_4O_{57}Si$ (2965.12): C, 60.36; H, 6.05; N, 1.89. Found: C, 60.27; H, 5.90; N, 1.80.

2-(Trimethylsilyl)ethyl O-*(methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)* -O-*(2,4,6 -tri*-O-*benzoyl-β*-D-*galactopyranosyl)- (1→3)*-O-*(2-acetamido-4,6-di*-O-*acetyl-2-deoxy-β*-D-*galactopyranosyl) -(1→4)- {*O-*[methyl 5-acetamido-8*-O- *(5-acetamido-4,7,8,9- tetra*-O *-acetyl-3,5 -dideoxy* -D -glycero-α -D -galacto-*2-nonulopyranosylono-1',9 -lactone) -4,7-di*-O *-acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)}*-O *-(2,6-di*-O *-acetyl-β*-D *-galactopyranosyl)-(1→4)-2,3, 6-tri*-O-*acetyl-β*-D-*glucopyranoside* (**28**). Removal of benzyl groups and subsequent *O*-acetylation of **27** (380 mg, 0.13 mmol), as described for **11**, gave **28** (315 mg, 91%) as an amorphous mass; $[\alpha]_D$ -15.8 (*c* 1.0, $CHCl_3$); *v* 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), 860 and 840 (Me_3Si), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.77-2.20 (21 s, 63 H, 4 AcN and 17 AcO), 2.43-2.63 (m, 3 H, H-3e-g-*eq*), 3.45 and 3.70 (2 s, 6 H, 2 MeO), 5.44 (d, 1 H, $J_{3,4}$ 3.6 Hz, H-4c), 5.53 (d, 1 H, $J_{3,4}$ 4.0 Hz, H-4d), and 7.28-8.18 (m, 15 H, 3 Ph). Anal. Calcd for $C_{121}H_{156}N_4O_{64}Si$ (2718.63): C, 53.46; H, 5.78; N, 2.06. Found: C, 53.28; H, 5.51; N, 2.03.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy*-D-*glycero*-α-D-*galacto-2-nonulopyranosylonate)-(2→3)*-O-*(2,4,6-tri*-O-*benzoyl-β*-D-*galactopyranosyl)-(1→3)*-O-*(2-acetamido-4,6-di*-O-*acetyl-2-deoxy-β*-D-*galactopyranosyl)-(1→4)-{*O-*[methyl 5-acetamido-8*-O-*(5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy*-D-*glycero*-α-D-*galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di*-O-*acetyl-3,5-dideoxy*-D-*glycero*-α-D-*galacto-2-nonulopyranosylonate]-(2→3)}*-O *-(2,6-di*-O *-acetyl-β* -D *-galactopyranosyl)-(1→4)-2,3,6-tri*-O *-acetyl*-D-*glucopyranose* (**29**). Removal of 2-(trimethylsilyl)ethyl group of **28** (330 mg, 0.12 mmol), as described for **12**, gave **29** (240 mg, 76%) as an amorphous mass; *v* 3600-3100 (OH, NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph). Anal. Calcd for $C_{116}H_{144}N_4O_{64}$ (2618.39): C, 53.21; H, 5.54; N, 2.14. Found: C, 53.04; H, 5.39; N, 1.98.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,4,6-tri*-O-*benzoyl-β*-D-*galactopyranosyl)-(1→3)*-O-*(2-acetamido-4,6-di*-O-*acetyl-2-deoxy-β*-D-*galactopyranosyl)-(1→4)-{*O-*[methyl 5-acetamido-8*-O-*(5-acetamido -4,7,8,9 -tetra*-O-*acetyl- 3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di*-O-*acetyl-3,5-dideoxy*-D-glycero-α -D-galacto-*2-nonulopyranosylonate]-(2→3) }*-O-*(2,6- di* -O-*acetyl-β*-D-*galactopyranosyl)-(1→4)-2,3,6 -tri*-O-*acetyl-α*-D-*glucopyranosyl trichloroacetimidate* (**30**). Treatment of **29** (240 mg, 0.09 mmol), as described for **13**, gave **30** (220 mg, 87%) as an amorphous mass; $[\alpha]_D$ +3.8 (*c* 1.0 $CHCl_3$); *v* 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.77-2.20 (21 s, 63 H, 4 AcN and 17 AcO), 2.43-2.71 (m, 3 H, H-3e-g-*eq*), 3.46 and 3.81 (2 s, 6 H, 2 MeO), 6.48 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1a), 7.39-8.18 (m, 15 H, 3 Ph), and 8.66 (s, 1 H, C=NH). Anal. Calcd for $C_{118}H_{144}Cl_3N_5O_{64}$ (2762.78): C, 51.30; H, 5.25; N, 2.53. Found: C, 51.15; H, 5.14; N, 2.33.

O-*(Methyl 5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)*-O-*(2,4,6-tri*-O-*benzoyl-β*-D-*galactopyranosyl)-(1→3)*-O-*(2-acetamido-4,6-di*-O-*acetyl-2-deoxy-β*-D-*galactopyranosyl)-(1→4)-{*O-*[methyl 5-acetamido-8*-O-*(5-acetamido-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-*

D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)}*-O*-(2,6-di-*O*-acetyl-β-D-galactopyranosyl)-(1→4)*-O*-(2,3,6-tri-*O*-acetyl-β-D-glucopyranosyl)-(1→1)-(2S,3R,4E)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol* (**31**). Condensation of **30** (220 mg, 0.08 mmol) with **14** (70 mg, 0.16 mmol), as described for **15**, gave **31** (132 mg, 58%) as an amorphous mass; $[\alpha]_D$ -14.4 (*c* 1.3, $CHCl_3$); *ν* 3300 (NH), 2200 (azide), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 0.88 (t, 3 H, $J_{Me,CH2}$ 6.7 Hz, *Me*CH_2), 1.24 (s, 22 H, 11 CH_2), 1.76-2.20 (21 s, 63 H, 4 AcN and 17 AcO), 2.43-2.65 (m, 3 H, H-3e-g-*eq*), 3.55 and 3.81 (2 s, 6 H, 2 MeO), 5.95 (dt, 1 H, $J_{4,5}$ 13.9, $J_{5,6} = J_{5,6'}$ = 7.3 Hz, H-5 of sphingosine), and 7.38-8.17 (m, 20 H, 4 Ph). Anal. Calcd for $C_{141}H_{181}N_7O_{66}$ (3029.98): C, 55.89; H, 6.02; N, 3.24. Found: C, 55.62; H, 5.85; N, 3.07.

*O-(Methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-*O*-(2,4,6-tri-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-*O*-(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)}-*O*-(2,6-di-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-D-glucopyranosyl)-(1→1)-(2S,3R,4E)-3-*O*-benzoyl-2-octadecanamido-4-octadecene-1,3-diol* (**32**). Treatment of **31** (132 mg, 0.05 mmol), as described for **16**, gave **32** (107 mg, 75%) as an amorphous mass; $[\alpha]_D$ -5.4 (*c* 1.1, $CHCl_3$); *ν* 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 0.88 (t, 6 H, $J_{Me,CH2}$ 6.7 Hz, 2 *Me*CH_2), 1.25 (s, 52 H, 26 CH_2), 1.76-2.20 (21 s, 63 H, 4 AcN and 17 AcO), 2.43-2.64 (m, 3 H, H-3e-g-*eq*), 3.45 and 3.80 (2 s, 6 H, 2 MeO), 5.90 (m, 1 H, H-5 of ceramide), and 7.39-8.17 (m, 20 H, 4 Ph). Anal. Calcd for $C_{159}H_{217}N_5O_{67}$ (3270.45): C, 58.39; H, 6,69; N, 2.14. Found: C, 58.16; H, 6.50; N, 1.93.

Ganglioside GT1b (**33**). De-*O*-acylation and saponification of methyl esters and lactone group in **32** (92 mg, 0.028 mmol), as described for **17**, gave **33** (60 mg, quantitative); $[\alpha]_D$ -12.9 (*c* 1.4, 5:5:1 $CHCl_3$-MeOH-H_2O); ^1H NMR [25:1 $(CD_3)_2SO$-D_2O] at 270 MHz: δ 0.85 (t, 6 H, $J_{Me,CH2}$ 7.1 Hz, 2 *Me*CH_2), 1.23 (s, 52 H, 26 CH_2), 1.76 and 1.87 (2 s, 12 H, 4 AcN), 2.34-2.75 (m, 4 H, H-3e-f-*eq*), 4.16 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1a), 4.31 (m, 2 H, H-1b and H-1d), 4.75 (d, 1 H, $J_{1,2}$ 8.8 Hz, H-1c), 5.33 (dd, 1 H, $J_{3,4}$ 7.5, $J_{4,5}$ 14.0 Hz, H-4 of ceramide), 5.53 (m, 1 H, H-5 of ceramide). Anal. Calcd for $C_{95}H_{165}N_5O_{47}$ (2129.35): C, 53.59; H, 7.81; N, 3.29. Found: C, 53.57; H, 7.78; N, 3.27.

2-(Trimethylsilyl)ethyl O-*[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)-*O*-(2,4,6-tri-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-*O*-(2-acetamido-6-*O*-benzyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)}-*O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside* (**35**). Glycosylation of **10** (500 mg, 0.25 mmol) with methyl *O*-[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate]-(2→3)-2,4,6-tri-*O*-benzoyl-1-thio-β-D-galactopyranoside[24] (**34**; 500 mg, 0.38 mmol), as described for **27**, gave **35** (430 mg, 52%) as an amorphous mass; $[\alpha]_D$ -17.2 (*c* 0.9, $CHCl_3$); *ν* 3600-3100 (OH, NH), 1750 and 1230 (ester), 1650 and 1540 (amide), 860 and 840 (Me_3Si), and 710 and 700 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270

MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.85-2.08 (17 s, 51 H, 5 AcN and 12 AcO), 2.28-2.76 (m, 3 H, H-3f-h*eq*), 3.18 and 3.32 (2 s, 6 H, 2 MeO), 5.72 (d, 1 H, $J_{3,4}$ 3.4 Hz, H-4d),and 7.03-8.09 (m, 45 H, 9 Ph). Anal. Calcd for $C_{164}H_{197}N_5O_{66}Si$ (3322.44): C, 52.29; H, 5.98; N, 2.11. Found: C, 59.02; H, 5.88; N, 1.93.

2-(Trimethylsilyl)ethyl O-*[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)-*O-*(2,4,6-tri-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-*O-*(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)}-*O-*(2,6-di-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-β-D-glucopyranoside* (**36**). Removal of benzyl groups and subsequent *O*-acetylation of **35** (470 mg, 0.14 mmol), as described for **11**, gave **36** (230 mg, 53%) as an amorphous mass; $[\alpha]_D$ -18.0 (*c* 0.7, $CHCl_3$); *v* 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), 860 and 840 (Me_3Si), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.00 (m, 2 H, $Me_3SiCH_2CH_2$), 1.88-2.13 (24 s, 72 H, 5 AcN and 19 AcO), 2.45-2.74 (m, 4 H, H-3e-h-*eq*), 3.24 and 3.27 (2 s, 6 H, 2 MeO), 5.44 (d, 1 H, $J_{3,4}$ 3.4 Hz, H-4c), 5.72 (d, 1 H, $J_{3,4}$ 3.4 Hz, H-4d), and 7.38-8.12 (m, 15 H, 3 Ph). Anal. Calcd for $C_{136}H_{175}N_5O_{73}Si$ (3075.94): C, 53.11; H, 5.73; N, 2.28. Found: C, 52.94; H, 5.57; N, 2.06.

*O-[Methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9- lactone) -4,7-di-*O*-acetyl- 3,5-dideoxy-*D-glycero- α-D-galacto- *2-nonulopyranosylonate]-(2→3)-*O-*(2,4,6-tri-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-*O-*(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2- nonulopyranosylonate]- (2→3)}-*O- *(2,6-di-*O*-acetyl-β-D-galactopyranosyl)- (1→4)- 2,3,6 -tri-*O*-acetyl-D-glucopyranose* (**37**). Removal of 2-(trimethylsilyl)ethyl group of **36** (210 mg, 0.07 mmol), as described for **12**, gave **37** (190 mg, 94%) as an amorphous mass; *v* 3600-3100 (OH, NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph). Anal. Calcd for $C_{131}H_{163}N_5O_{73}$ (2975.71): C, 52.88; H, 5.52; N, 2.35. Found: C, 52.68; H, 5.45; N, 2.15.

*O-[Methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono- 1',9- lactone)-4,7- di-*O*-acetyl-3,5 -dideoxy- *D-glycero-α-D-galacto-*2- nonulopyranosylonate]-(2→3)-*O-*(2,4,6-tri-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-*O-*(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-{O-[methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9-lactone)-4,7-di-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate]-(2→3)} -O-(2,6 -di-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6 -tri-*O* -acetyl-α-D-glucopyranosyl trichloroacetimidate* (**38**). Treatment of **37** (70 mg, 0.02 mmol), as described for **13**, gave **38** (50 mg, 95%) as an amorphous mass; $[\alpha]_D$ -6.5 (*c* 1.1, $CHCl_3$), v 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 1.87-2.19 (24 s, 72 H, 5 AcN and 19 AcO), 2.44-2.66 (m, 4 H, H-3e-h-*eq*), 3.25 and 3.47 (2 s, 6 H, 2 MeO), 5.73 (d, 1 H, $J_{3,4}$ 3.7 Hz, H-4d), 6.47 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1a), and 7.27-8.12 (m, 15 H, 3 Ph). Anal. Calcd for $C_{133}H_{163}Cl_3N_6O_{73}$ (3120.10): C, 51.20; H, 5.27; N, 2.69. Found: C, 51.18; H, 5.09; N, 2.55.

*O-[Methyl 5-acetamido-8-*O*-(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylono-1',9 -lactone)-4,7 -di-*O*-acetyl-3,5 -dideoxy -D-glycero-α-D-galacto-2 -nonulopyranosylonate]-(2→3) -O-(2,4,6-tri-*O*-benzoyl-β-D-galactopyranosyl)-(1→3)-*O-*(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-*

β-D-*galactopyranosyl)-(1→4)-{*O-*[methyl 5-acetamido-8-*O-*(5-acetamido-4,7,8,9-tetra-*O-*acetyl-3,5-dideoxy-*D-glycero-*α*-D-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-*O-*acetyl-3,5-dideoxy-*D-glycero-*α*-D-galacto-2-nonulopyranosylonate]-(2→3)}* -O *-(2,6-di-*O *-acetyl-β-*D-*galactopyranosyl)-(1→4)-*O-*(2,3,6-tri-*O-*acetyl-β-*D-*glucopyranosyl)-(1→1)-(*2S,3R,4E*)-2-azido-3-*O-*benzoyl-4-octadecene-1,3-diol* (**39**). Condensation of **38** (50 mg, 0.02 mmol) with **14** (15 mg, 0.03 mmol), as described for **15**, gave **39** (25 mg, 46%) as an amorphous mass; $[\alpha]_D$ -39.4 (*c* 0.3, $CHCl_3$); *ν* 3300 (NH), 2200 (azide), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 0.88 (t, 3 H, $J_{Me,CH2}$ 6.9 Hz, *Me*CH_2), 1.25 (s, 22 H, 11 CH_2), 1.81-2.20 (24 s, 72 H, 5 AcN and 19 AcO), 2.47-2.72 (m, 4 H, H-3e-h-*eq*), 3.25 and 3.48 (2 s, 6 H, 2 MeO), 5.73 (d, 1 H, $J_{3,4}$ 3.6 Hz, H-4d), 5.87 (m, 1 H, H-5 of sphingosine), and 7.32-8.20 (m, 20 H, 4 Ph). Anal. Calcd for $C_{156}H_{200}N_8O_{75}$ (3387.30): C, 55.32; H, 5.95; N, 3.31. Found: C, 55.08; H, 5.77; N, 3.01.

O-*[Methyl 5-acetamido-8-*O-*(5-acetamido-4,7,8,9-tetra-*O-*acetyl-3,5-dideoxy-*D-glycero-*α*-D-galacto-2-nonulopyranosylono-1',9 -lactone)- 4,7-di-*O-*acetyl-3,5 -dideoxy* -D-glycero-*α* -D-galacto-2- *nonulopyranosylonate]-(2→3)-*O-*(2,4,6-tri-*O-*benzoyl-β-*D-*galactopyranosyl)-(1→3)-*O-*(2-acetamido-4,6-di-*O-*acetyl-2-deoxy-β-*D-*galactopyranosyl)-(1→4)-{*O-*[methyl 5-acetamido-8-*O-*(5-acetamido-4,7,8,9-tetra-*O-*acetyl-3,5-dideoxy-*D-glycero-*α*-D-galacto-2-nonulopyranosylono-1',9-lactone)-4,7-di-*O-*acetyl-3,5-dideoxy-*D-glycero-*α* -D-galacto-2-nonulopyranosylonate]-(2→3)}-*O-*(2,6-di-*O-*acetyl-β* -D-*galactopyranosyl)-(1→4)-*O *-(2,3,6-tri-*O *-acetyl-β-*D-*glucopyranosyl)-(1→1)-(*2S,3R,4E*)-3-*O-*benzoyl-2-octadecanamido-4-octadecene-1,3-diol* (**40**). Treatment of **39** (35 mg, 0.01 mmol), as described for **16**, gave **40** (16 mg, 43%) as an amorphous mass; $[\alpha]_D$ -9.4 (*c* 0.5, $CHCl_3$); *ν* 3300 (NH), 1750 and 1230 (ester), 1650 and 1540 (amide), and 710 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) at 270 MHz: δ 0.88 (t, 6 H, $J_{Me,CH2}$ 7.1 Hz, 2 *Me*CH_2), 1.25 (s, 52 H, 26 CH_2), 1.85-2.19 (24 s, 72 H, 5 AcN and 19 AcO), 2.24-2.63 (m, 4 H, H-3e-h-*eq*), 3.25 and 3.48 (2 s, 6 H, 2 MeO), 5.72 (d, 1 H, $J_{3,4}$ 3.6 Hz, H-4d), 5.87 (m, 1 H, H-5 of ceramide), and 7.29-8.12 (m, 20 H, 4 Ph). Anal. Calcd for $C_{174}H_{236}N_6O_{76}$ (3627.77): C, 57.61; H, 6.56; N, 2.32. Found: C, 57.43; H, 6.38; N, 2.10.

Ganglioside GQ1b (**41**). De-*O*-acylation and saponification of methyl esters and lactone groups in **40** (10 mg, 2.8 μmol), as described for **17**, gave **41** (7 mg, quantitative); $[\alpha]_D$ -22.0 (*c* 0.2, 5:5:1 $CHCl_3$-MeOH-H_2O); ^1H NMR [25:1 $(CD_3)_2SO$-D_2O] at 500 MHz: δ 0.85 (t, 6 H, $J_{Me,CH2}$ 7.1 Hz, 2 *Me*CH_2), 1.23 (s, 52 H, 26 CH_2), 1.84 and 1.88 (2 s, 15 H, 5 AcN), 2.34-2.75 (m, 4 H, H-3e-f-*eq*), 4.16 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1a), 4.31 (m, 2 H, H-1b and H-1d), 4.75 (d, 1 H, $J_{1,2}$ 8.8 Hz, H-1c), 5.33 (dd, 1 H, $J_{3,4}$ 7.5, $J_{4,5}$ 14.0 Hz, H-4 of ceramide), 5.53 (m, 1 H, H-5 of ceramide). Anal. Calcd for $C_{106}H_{182}N_6O_{55}$ (2420.61): C, 52.60; H, 7.58; N, 3.47. Found: C, 52.35; H, 7.47; N, 3.46.

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