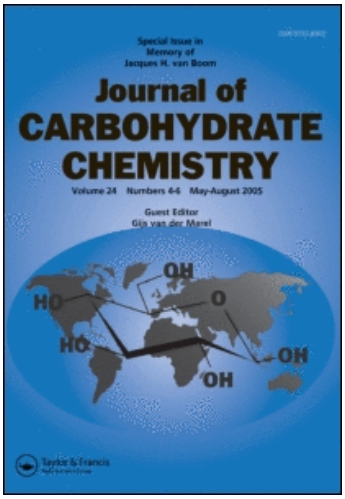

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SYNTHETIC STUDIES ON SIALOGLYCOCONJUGATES 41: A FACILE TOTAL SYNTHESIS OF GANGLIOSIDE GM_2

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ABSTRACT

A stereocontrolled, facile total synthesis of ganglioside GM_2 is described. Coupling of 2- (trimethylsilyl)ethyl *O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (**2**), prepared from 2-(trimethylsilyl)ethyl β-lactoside (**1**) by selective 3',4'-*O*-isopropylidenation, *O*-benzylation, and subsequent removal of the isopropylidene group, with methyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy -2-thio-D-*glycero*-D-*galacto* -2-nonulopyranosid)onate (**4**) using *N*-iodosuccinimide (NIS), gave the trisaccharide (**5**), which on condensation with methyl 6-*O*-benzoyl -2-deoxy-3,4-*O*-isopropylidene-2-phthalimido-1-thio-β-D-galactopyranoside (**11**) , gave the protected ganglioside GM_2 oligosaccharide **12**. Compound **12** was transformed, *via* *O*-deisopropylidenation, *O*-acetylation, removal of the phthaloyl group, *N*-acetylation, removal of the benzyl groups followed by *O*-acetylation, selective removal of the 2-(trimethylsilyl)ethyl group, and subsequent imidate formation, into the final glycosyl donor **19**. Glycosylation of (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol (**20**) with the α-trichloroacetimidate **19** gave the β-glycoside **21**, which on channeling through selective reduction of the azide group, coupling of the amino group with octadecanoic acid, *O*-deacylation and saponification of the methyl ester group, gave the title ganglioside.

INTRODUCTION

Studies[1] on the isolation and characterization of various gangliosides from normal and pathogenic tissues have demonstrated their involvement not only as modulators but also as biologically active compounds in biological systems. An approach toward a

systematic understanding of the structural and functional intricacies of the gangliosides necessitates efficient regio-and stereo-controlled synthetic routes, affording various gangliosides and their analogs. The important point in the synthesis of gangliosides has been the stereoselective and high yield α-glycosylation of sialic acid with various sugar residues. Recently, we have demonstrated a facile procedure[2,3] for α-glycosylation with thioglycosides of sialic acid, using dimethyl(methylthio)sulfonium triflate (DMTST)[4] or *N*-iodosuccinimide (NIS)-trifluoromethanesulfonic acid as the glycosyl promoter for the reactions with the suitably protected galactose and lactose acceptors in acetonitrile.[5,6] From the application of this procedure, we have reported the systematic synthesis of lacto[7] and neolacto[7b,7c,8,9] series of gangliosides, ganglioside GM_3[10] and GM_4, [11] and their analogs,[12] to be used in pursuit of our objective of elucidating the functions of sialoglycoconjugates. Here we describe a facile total synthesis of ganglioside GM_2 in connection with developement of the systematic synthesis of ganglio-series of gangliosides. Ganglioside GM_2 was first isolated[13] from the brains of patients with Tay-Sachs disease, and is widely found in brain[14] as well as in visceral organs.[15] A total synthesis of this ganglioside was first achieved by Ogawa *et al.*. [16]

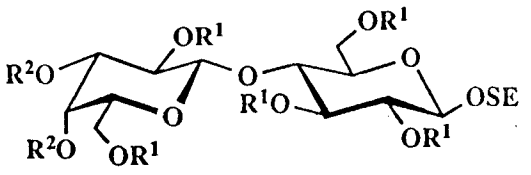
RESULTS AND DISCUSSION

For the systematic synthesis of ganglio-series gangliosides, 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*- (2,6-di-*O*-benzyl-β-D-galactopyranosyl) -(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (**5**) was selected as the glycosyl acceptor, and methyl 6-*O* -benzoyl - 2- deoxy-3,4-*O*-isopropylidene-2-phthalimido-1-thio-β-D-galactopyranoside (**11**) as the glycosyl donor.

Treatment of 2-(trimethylsilyl)ethyl β-lactoside[17] (**1**) with 2,2-dimethoxypropane (2 equiv to **1**) in *N,N*-dimethylformamide (DMF) containing *p*-toluenesulfonic acid at 80 °C gave the 3,4-*O*-isopropylidene derivative, which on per-*O*-benzylation with benzyl bromide in the presence of sodium hydride and subsequent *O*-deisopropylidenation, afforded 2-(trimethylsilyl)ethyl *O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)- (1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (**2**) in 70% yield. The structure of **2**, after acetylation, was unambiguously proved by 270 MHz ^{1}H NMR spectroscopy. Significant signals in the ^{1}H NMR spectrum of **3** obtained by *O*-acetylation of **2** were two three-proton singlets at δ 1.90 and 1.94 (2AcO), a one-proton doublet of doublets at δ 4.83 ($J_{2',3'}$ = 6.6 Hz, $J_{3',4'}$ = 3.5 Hz, H-3') and a one-proton doublet at δ 5.35 (H-4'), indicating the

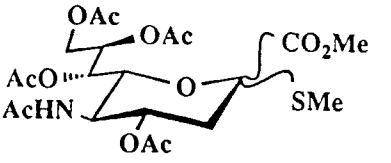
structure assigned. The glycosylation of **2** with methyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-2-thio-D-*glycero*-D-*galacto*-2-nonulopyranosid)onate[3a] (**4**; 2.0 equiv to the glycosyl acceptor) in acetonitrile for 2 h at -35 °C in the presence of *N*-iodosuccinimide (NIS)-trifluoromethanesulfonic acid (TfOH), and powdered molecular sieves 3Å (MS-3Å) afforded the desired α-glycoside **5** of Neu5Ac in 59% yield. Acetylation of **5** with acetic anhydride in pyridine gave the acetate **6** in quantitative yield. The observed chemical shifts and coupling constants of the Neu5Ac unit for H-3e (δ 2.58, $J_{3a,3e}$ = 12.5 Hz, $J_{3e,4}$ = 4.6 Hz), H-4 (δ 4.95) and H-7 (δ 5.30, $J_{6,7}$ = 2.4 Hz, $J_{7,8}$ = 8.5 Hz), are characteristic of the α-glycosidic linkages[2a,18] of Neu5Ac. Other ^{1}H NMR data are given in the Experimental Section and are consistent with the structure assigned.

Methyl 6-*O*-benzoyl-2-deoxy-3,4-*O*-isopropylidene-2-phthalimido-1-thio-β-D-galactopyranoside (**11**) as the key donor, was obtained in good yield from 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-phthalimido-β-D-galactopyranoside[19] (**7**) *via* replacement of the anomeric acetoxy group with methylthio group by use of (methylthio)trimethylsilane in the presence of trimethylsilyl trifluoromethanesulfonate, *O*-deacetylation, selective 3,4-*O*-isopropylidenation and then 6-*O*-benzoylation. Significant signals of **11** were two three-proton singlets at δ 1.35 and 1.66 (Me_2C), a three-proton singlet at δ 2.15 (MeS), a one-proton doublet of doublets at δ 4.40 ($J_{1,2}$ = 10.6 Hz, $J_{2,3}$ = 8.9 Hz, H-2), a one-proton doublet at δ 4.67 ($J_{3,4}$ = 4.9 Hz, H-4), a one-proton doublet of doublets at δ 4.88 (H-3), and a one-proton doublet at δ 5.13 (H-1), indicating the structure assigned.
The glycosylation of **5** with compound **11** thus obtained, in the presence of NIS-TfOH as the glycosyl promoter and molecular sieves 4Å (MS-4Å) in dichloromethane for 2 h at 0 °C gave the desired β-glycoside **12** in 68% yield. Removal of the isopropylidene group from **12** with aqueous 80% acetic acid at 50 °C gave **13** in 80% yield, after column chromatography. Acetylation of **13** and subsequent treatment[16] with lithium iodide in pyridine gave compound **15** in high yield. Treatment of **15** with hydrazine monohydrate in ethanol, follwed by *N*-and *O*-acetylation, and then methyl esterification of the carboxyl group with diazomethane in methanol, afforded compound **16** in 80% yield. Catalytic hydrogenolysis (10% Pd-C) of the benzyl groups of **16** in ethanol-acetic acid (3:1) for 24 h at 45 °C, and subsequent *O*-acetylation gave the per-*O*-acetyl compound **17** in 95% yield. Treatment[17b] of **17** with trifluoroacetic acid in dichloromethane for 1.5 h at room temperature gave the 1-hydroxy compound **18** quantitatively. When treated[20] with trichloroacetonitrile in dichloromethane in the presence of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) for 3 h at 0 °C, **18** gave the α-trichloroacetimidate **19** in 84% yield. Significant signals in the ^{1}H NMR spectrum of **19** were a one-proton doublet at δ 6.50 ($J_{1,2}$ = 3.8 Hz, H-1) and a one-proton singlet at δ



	R^1	R^2
1	H	H
2	Bn	H
3	Bn	Ac

SE = 2-(trimethylsilyl)ethyl
Bn = benzyl



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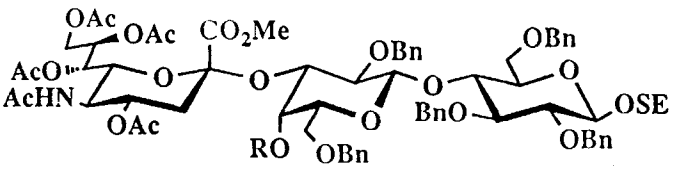
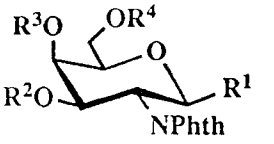
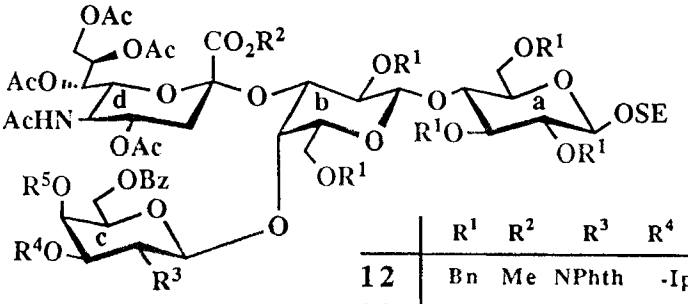


5 R = H
6 R = Ac

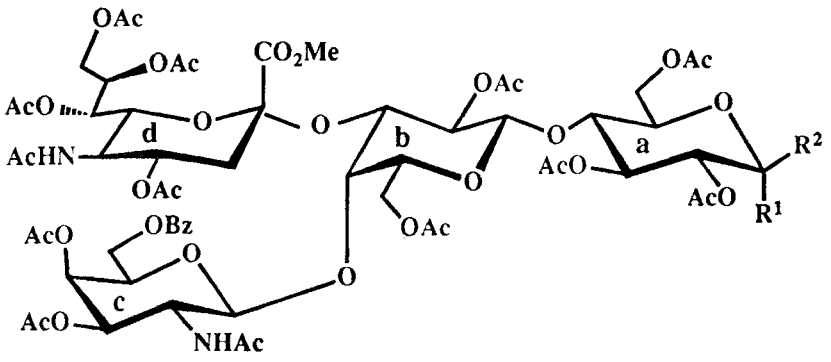


	R^1	R^2	R^3	R^4
7	OAc	Ac	Ac	Ac
8	SMe	Ac	Ac	Ac
9	SMe	H	H	H
10	SMe	-Ipd-		H
11	SMe	-Ipd-		Bz

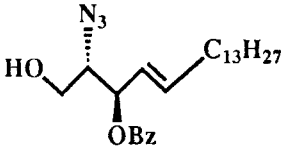
Phth = phthaloyl
Ipd = isopropylidene
Bz = benzoyl



	R^1	R^2	R^3	R^4	R^5
12	Bn	Me	NPhth	-Ipd-	
13	Bn	Me	NPhth	H	H
14	Bn	Me	NPhth	Ac	Ac
15	Bn	H	NPhth	Ac	Ac
16	Bn	Me	NHAc	Ac	Ac
17	Ac	Me	NHAc	Ac	Ac



	R^1	R^2
18	- H , OH -	
19	$OC(=NH)CCl_3$	H



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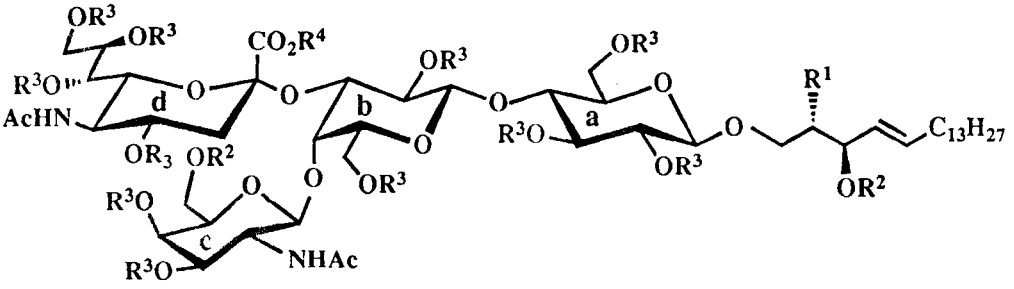

	R^1	R^2	R^3	R^4
21	N_3	Bz	Ac	Me
22	$NHCO(CH_2)_{16}Me$	Bz	Ac	Me
23	$NHCO(CH_2)_{16}Me$	H	H	H

8.66 (C=NH), indicating the α-trichloroacetimidate formation. Other ^{1}H NMR data were consistent with the structure **19**.

The final glycosylation of (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol (**20**)[21] with **19** thus obtained, in dichloromethane in the presence of trimethylsilyl trifluoromethanesulfonate for 24 h at 0 °C gave only the expected β-glycoside **21** in 41% yield. The observed chemical shifts and coupling constants due to the newly coupled 2-azido-sphingosine analog were a one-proton doublet at δ 4.49 ($J_{1,2}$ = 7.8 Hz, H-1a) and a three-proton triplet at δ 1.12 (*Me*CH_2). Selective reduction[21b,22] of the azide group in **21** with hydrogen sulfide in aqueous pyridine gave the amine, which on condensation with octadecanoic acid by use of 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide (WSC) in dichloromethane, afforded the acylated ganglioside GM_2 **22** in 73% yield, after chromatography. Finally, *O*-deacylation of **22** with sodium methoxide in methanol, with subsequent saponification of the methyl ester group, yielded GM_2 in quantitative yield after chromatography on a column of Sephadex LH-20.

The work described above shows that the use of the thioglycoside of Neu5Ac in the presence of the thiophilic promoter (NIS-TfOH) in acetonitrile under kinetically controlled conditions is effective for the synthesis of the α-glycoside of Neu5Ac with sterically hindered glycosyl acceptor. The above mentioned 2-(trimethylsilyl)ethyl di- and tetrasaccharides (**2** and **13**) could be further used as building blocks for systematic synthesis of ganglio-series gangliosides.

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 Chemical Co., 200 mesh) with the solvent systems specified. Concentrations were conducted *in vacuo*.

2-(Trimethylsilyl)ethyl *O*-(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*-β-D-galactopyranosyl-(1→4)-β-D-glucopyranoside[17] (**1**; 10.0 g, 22.6 mmol) in *N*,*N*-dimethylformamide (DMF; 200 mL) and 2,2-dimethoxypropane (5.5 mL, 2.0 equiv to **1**) was added Drierite (10 g), and the mixture was stirred for 1 h at room temperature. *p*-Toluenesulfonic acid monohydrate (100 mg) was added; the pH of the solution reached to about 3. The mixture was heated, with stirring, at 80 °C while the progress of

reaction was monitored by TLC, then neutralized with $NaHCO_3$. The precipitate was filtered off, and the solution was concentrated. To a solution of the residue in DMF (150 mL) was added a suspension of sodium hydride in oil (8.6 g, 60% of sodium hydride by weight). The mixture was stirred for 5 min at 0 °C, benzyl bromide (25.6 mL, 8.6 equiv) was added dropwise, and stirring was continued for 22 h at room temperature. The reaction was monitored by TLC, and when complete, methanol (3 mL) was added, and the mixture was concentrated and extracted with dichloromethane. The extract was washed with 2 M hydrochloric acid and water, dried (Na_2SO_4) and concentrated. A solution of the residue in aqueous 80% acetic acid (150 mL) was heated for 2 h at 50 °C and concentrated. Column chromatography (1:4 ethyl acetate-hexane) of the residue on silica gel (500 g) gave **2** (13 g, 70%) as an amorphous mass: $[\alpha]_D$ +16.7° (*c* 0.76, $CHCl_3$); IR (KBr) 3650-3150 (OH), 860 and 840 (TMS), and 730 cm^{-1} (Ph).

Anal. Calcd for $C_{52}H_{64}O_{11}Si$ (893.2): C, 69.93; H, 7.22. Found: C, 69.81; H, 7.34.

A sample (50 mg) of **2** was acetylated with acetic anhydride (1 mL) in pyridine (2 mL) to give the di-*O*-acetyl derivative **3** (55 mg, quantitative) as an amorphous mass: $[\alpha]_D$ -5.3° (*c* 1.2, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.00 (m, 2H, $Me_3SiCH_2CH_2$), 1.90, 1.94 (2s, 6H, 2AcO), 4.83 (dd, 1H, $J_{2',3'}$ = 6.6 Hz, $J_{3',4'}$ = 3.5 Hz, H-3'), 5.35 (broad d, 1H, H-4'), and 7.15-7.35 (m, 25H, 5Ph).

Anal. Calcd for $C_{56}H_{68}O_{13}Si$ (977.2): C, 68.83; H, 7.01. Found: C, 68.77; H, 7.13.

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*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (5).

To a solution of **3** (1.0 g, 1.25 mmol) and methyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-2-thio-D-*glycero*-D-*galacto*-2-nonulopyranosid)onate[3a] (**4**; 1.42 g, 2.49 mmol) in dry acetonitrile (10 mL) was added molecular sieve 3Å (MS-3Å; 3.0 g), and the mixture was stirred for 5 h at room temperature then cooled to -35 °C. To the cooled mixture were added, with stirring, *N*-iodosuccinimide (NIS; 1.12 g, 4.98 mmol) and trifluoromethanesulfonic acid (TfOH; 44 μL), and the stirring was continued for 2 h at -35 °C. The precipitate was filtered off, and washed thoroughly with dichloromethane. The filtrate and washings were combined, and the solution was successively washed with M Na_2CO_3, M $Na_2S_2O_3$ and water, dried (Na_2SO_4) and concentrated. Column chromatography (50:1 toluene-methanol) of the residue on silica gel (150 g) gave **5** (980 mg, 59%) as an amorphous mass: $[\alpha]_D$ +4.2° (*c* 0.9, $CHCl_3$); IR (KBr) 3700-3150 (OH, NH), 1740 and 1220 (ester), 1660 and 1535 (amide), 860 and 840

(TMS), and 730 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) Lac. unit δ 1.00 (m, 2H, $Me_3SiCH_2CH_2$), and 7.18-7.38 (m, 25H, 5Ph); Neu5Ac unit δ 1.85 (s, 3H, AcN), 1.87, 1.96, 1.99, 2.07 (4s, 12H, 4AcO), 2.47 (dd, 1H, Jgem = 13.0 Hz, $J_{3e,4}$ = 4.8 Hz, H-3e), 3.83 (s, 3H, MeO), 4.86 (m, 1H, H-4), 5.25 (d, 1H, $J_{5,NH}$ = 7.2 Hz, NH), 5.28 (dd, 1H, $J_{6,7}$ = 1.6 Hz, $J_{7,8}$ = 7.0 Hz, H-7), and 5.36 (ddd, 1H, H-8).

Anal. Calcd for $C_{72}H_{91}NO_{23}Si$ (1366.5): C, 63.28; H, 6.71; N, 1.02. Found: C, 63.14; H, 6.88; N, 1.11.

A sample (50 mg) of **5** was acetylated with acetic anhydride (1 mL) in pyridine (2 mL) to give **6** (53 mg, quantitative) as an amorphous mass: $[\alpha]_D$ -6.6° (*c* 1.4, chloroform); ^1H NMR ($CDCl_3$) Lac. unit δ 1.00 (m, 2H, $Me_3SiCH_2CH_2$), 5.03 (broad, d, 1H, $J_{3',4'}$ = 3.1 Hz, H-4'), and 7.14-7.40 (m, 25H, 5Ph); Neu5Ac unit δ 1.74 (s, 3H, AcN), 2.58 (dd, 1H, Jgem = 12.5 Hz, $J_{3e,4}$ = 4.6 Hz, H-3e), 4.95 (m, 1H, H-4), 5.12 (d, 1H, $J_{5,NH}$ = 10.2 Hz, NH), 5.30 (dd, 1H, $J_{6,7}$ = 2.4 Hz, $J_{7,8}$ = 8.5 Hz, H-7), and 5.57 (m, 1H, H-8); *O*-acetyl groups δ 1.83, 1.95, 1.98, 1.99 and 2.08 (5s, 15H, 5AcO).

Anal. Calcd for $C_{74}H_{93}NO_{24}Si$ (1408.6): C, 63.09; H, 6.66; N, 0.99. Found: C, 63.15; H, 6.73; N, 1.12.

Methyl 3,4,6 -Tri -*O* - acetyl -2-deoxy-2-phthalimido - 1-thio-β-D-galactopyranoside (8). To a stirred solution of 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-phthalimido-β-D-galactopyranose[19] (**7**; 3.0 g, 6.28 mmol) in dry 1,2-dichloroethane (30 mL) were added (methylthio)trimethylsilane (1.93 g, 15.7 mmol) and trimethylsilyl trifluoromethanesulfonate (TMS-triflate; 0.62 mL, 3.14 mmol). The mixture was then heated, with stirring, for 24 h at 40 °C, the course of the reaction being monitored by TLC. Dichloromethane (100 mL) was added, and the mixture was successively washed with M Na_2CO_3 and water, dried (Na_2SO_4) and concentrated. Column chromatography (1:3 ethyl acetate-hexane) of the residue on silica gel (150 g) gave **8** (2.8 g, 95%) as an amorphous mass: $[\alpha]_D$ +13.5° (*c* 0.57, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.86, 2.07, 2.19 (3s, 9H, 3AcO), 2.21 (s, 3H, MeS), 4.63 (dd, 1H, $J_{1,2}$ = 10.4 Hz, $J_{2,3}$ = 11.0 Hz, H-2), 5.35 (d, 1H, H-1), 5.53 (d, 1H, $J_{3,4}$ = 3.3 Hz, H-4), and 5.87 (dd, 1H, H-3).

Anal. Calcd for $C_{21}H_{23}NO_9S$ (465.5): C, 54.19; H, 4.98; N, 3.01. Found: C, 54.28; H, 4.99; N, 2.86.

Methyl 2-Deoxy-2-phthalimido-1-thio-β-D-galactopyranoside (9). To a solution of **8** (2.47 g, 5.3 mmol) in methanol (30 mL) was added sodium methoxide (30 mg), and the mixture was stirred for 10 min at room temperature, then treated with Amberlite IR-120 (H^+) resin to remove the base. The solution was concentrated, and the residue was chromatographed on a column of silica gel (50 g) with ethyl acetate to give **9** (1.65 g, 92%) as needles: mp 125-127 °C, $[\alpha]_D$ +18.0° (*c* 0.84, $CHCl_3$); ^1H NMR ($CDCl_3$) δ

2.25 (s, 3H, MeS), 3.82 (t, 1H, $J_{1,2} = J_{2,3} = 10.9$ Hz, H-2), 3.91 (dd, 1H, $J_{3,4} = 3.9$ Hz, H-3), 5.25 (d, 1H, H-1), and 7.90-8.00 (m, 4H, Ph).

Anal. Calcd for $C_{15}H_{17}NO_6S$ (339.4): C, 53.09; H, 5.05; N, 4.13. Found: C, 53.10; H, 5.16; N, 4.02.

Methyl 2-Deoxy-3,4-*O*-isopropylidene-2-phthalimido-1-thio-β-D-galactopyranoside (10). To a solution of **9** (3.65 g, 10.8 mmol) in DMF (37 mL) was added Drierite (4.0 g), and the mixture was stirred for 1 h at room temperature. 2,2-Dimethoxypropane (2.6 mL, 21.5 mmol) and *p*-toluenesulfonic acid monohydrate (60 mg) were added, and the mixture was stirred for 4 h at 80 °C while the course of reaction was monitored by TLC, then neutralized with $NaHCO_3$. The precipitate was filtered off, and the solution was concentrated to a syrup that was chromatographed on a column of silica gel (150 g) with 1:2 ethyl acetate-hexane to give **10** (2.7 g, 66%) as needles: mp 148-150 °C, $[\alpha]_D$ +82.5° (*c* 0.7, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.34, 1.62 (2s, 6H, Me_2C), 2.16 (s, 3H, MeS), 3.86 (dd, 1H, $J_{5,6} = 3.5$ Hz, Jgem = 11.4 Hz, H-6), 4.29 (dd, 1H, $J_{3,4} = 5.1$ Hz, $J_{4,5} = 2.0$ Hz, H-4), 4.36 (dd, 1H, $J_{1,2} = 10.6$ Hz, $J_{2,3} = 9.0$ Hz, H-2), 4.85 (dd, 1H, H-3), 5.10 (d, 1H, H-1), and 7.28-7.89 (m, 4H, Ph).

Anal. Calcd for $C_{18}H_{21}NO_6S$ (379.4): C, 56.98; H, 5.58; N, 3.69. Found: C, 56.88; H, 5.74; N, 3.70.

Methyl 6-*O*-Benzoyl-2-deoxy-3,4-*O*-isopropylidene-2-phthalimido-1-thio-β-D-galactopyranoside (11). To a stirred solution of **10** (700 mg, 1.84 mmol) in dichloromethane (7 mL) and pyridine (0.3 mL) was added benzoyl chloride (0.26 mL, 2.21 mmol) at 0 °C. The mixture was stirred for 1 h at room temperature, and methanol (0.5 mL) was added. The solution was concentrated to a syrup which was extracted with dichloromethane. The extract was successively washed with 2 M hydrochloric acid and water, dried (Na_2SO_4) and concentrated. Column chromatography (1:6 ethyl acetate-hexane) of the residue on silica gel (40g) gave **11** (890 mg, quantitative) as an amorphous mass: $[\alpha]_D$ +66.8° (*c* 0.76, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.35, 1.66 (2s, 6H, Me_2C), 2.15 (s, 3H, MeS), 4.40 (dd, 1H, $J_{1,2} = 10.6$ Hz, $J_{2,3} = 8.9$ Hz, H-2), 4.67 (d, 1H, $J_{3,4} = 4.9$ Hz, H-4), 4.88 (dd, 1H, H-3), 5.13 (d, 1H, H-1), and 7.28-8.05 (m, 9H, 2Ph).

Anal. Calcd for $C_{25}H_{25}NO_7S$ (483.5): C, 62.10; H, 5.21; N, 2.90. Found: C, 61.96; H, 5.38; N, 2.72.

2-(Trimethylsilyl)ethyl*O*-(6-*O*-Benzoyl-2-deoxy-3,4-*O*-isopropylidene-2-phthalimido-β-D-galactopyranosyl)-(1→4)-*O*-[(methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate) - (2→3)] -*O* - (2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (12). To a solution of **11** (36 mg, 0.07 mmol) and **5** (70 mg, 0.05 mmol) in dichloromethane

(0.7 mL) was added MS-4Å (200 mg), and the mixture was stirred for 5 h at room temperature and cooled to 0 °C. *N*-Iodosuccinimide (34.6 mg, 0.15 mmol) and TfOH (1.3 μL) were added at 0 °C, and the mixture was stirred for 2 h while the progress of reaction was monitored by TLC. The precipitate was collected and washed with dichloromethane, and the combined filtrate and washings were successively washed with M Na_2CO_3, M $Na_2S_2O_3$ and water, dried (Na_2SO_4) and concentrated. Column chromatography (3:1 ethyl acetate-hexane) of the residue on silica gel (30 g) gave **12** (62 mg, 68%) as an amorphous mass: $[\alpha]_D$ +26.5° (*c* 0.7, $CHCl_3$); IR (KBr) 3300 (NH), 1740 and 1220 (ester), 1660 and 1550 (amide), 860 and 840 (TMS, Me_2C), and 730 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) δ 1.00 (m, 2H, $Me_3SiCH_2CH_2$), 1.34, 1.53 (2s, 6H, Me_2C), 1.72 (s, 3H, AcN), 1.83, 1.89, 2.03, 2.04 (4s, 12H, 4AcO), 2.76 (dd, 1H, Jgem = 12.7 Hz, $J_{3eq,4}$ = 3.4 Hz, H-3d-*eq*), 2.81 (dd, 1H, $J_{1,2}$ = 7.1 Hz, $J_{2,3}$ = 9.5 Hz, H-2b), 3.76 (s, 3H, MeO), 3.95 (dd, 1H, $J_{3,4}$ = 2.8 Hz, H-3b), 4.37 (d, 1H, H-1b), 4.74 (m, 1H, H-4d), 5.36 (m, 1H, H-8d), and 6.95-8.01 (m, 34H, 7Ph).

Anal. Calcd for $C_{96}H_{112}N_2O_{30}Si$ (1802.0): C, 63.99; H, 6.26; N, 1.55. Found: C, 63.85; H, 6.43; N, 1.37.

2-(Trimethylsilyl)ethyl *O*-(6-*O*-Benzoyl-2-deoxy-2-phthalimido-β-D-galacto-pyranosyl)-(1→4)-*O*-[(methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate) - (2→3)]-*O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (13). A solution of **12** (213 mg, 0.12 mmol) in aqueous 80% acetic acid (5 mL) was heated overnight at 50 °C and concentrated. Column chromatography (50:1 dichloromethane-methanol) of the residue on silica gel (25 g) gave **13** (166 mg, 80%) as an amorphous mass: $[\alpha]_D$ +21.3° (*c* 1.71, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.00 (m, 2H, $Me_3SiCH_2CH_2$), 1.69 (s, 3H, AcN), 1.83, 1.88, 2.02, 2.04 (4s, 12H, 4AcO), 2.74 (dd, 1H, Jgem = 12.7 Hz, $J_{3eq,4}$ = 3.9 Hz, H-3d-eq), 2.86 (dd, 1H, $J_{1,2}$ = 7.5 Hz, $J_{2,3}$ = 9.5 Hz, H-2b), 3.80 (s, 3H, MeO), 3.96 (d, 1H, H-1b), 5.37 (m, 1H, H-8d), and 7.11-8.01 (m, 34H, 7Ph).

Anal. Calcd for $C_{93}H_{108}N_2O_{30}Si$ (1762.0): C, 63.40; H, 6.18; N, 1.59. Found: C, 63.37; H, 6.33; N, 1.51.

A sample of **13** (166 mg, 0.09 mmol) was acetylated with acetic anhydride (1.5 mL) in pyridine (2 mL) for 24 h at room temperature. The product was purified by column chromatography (60:1 dichloromethane-methanol) on silica gel (30 g) to give **14** (158 mg, 91%) as an amorphous mass: $[\alpha]_D$ +6.5° (*c* 0.54, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.00 (m, 2H, $Me_3SiCH_2CH_2$), 1.70 (s, 3H, AcN), 1.82, 1.83, 1.90, 2.02, 2.05, 2.23 (6s, 18H, 6AcO), 2.76 (dd, 1H, Jgem = 12.8 Hz, $J_{3eq,4}$ = 3.9 Hz, H-3d-eq), 2.83 (dd, 1H, $J_{1,2}$ = 7.0 Hz, $J_{2,3}$ = 9.9 Hz, H-3b), 3.73 (d, 1H, $J_{3,4}$ = 3.8 Hz, H-4b), 3.85 (s, 3H, MeO), 4.07 (dd,

1H, H-3b), 4.50 (d, 1H, H-1b), 4.64 (dd, 1H, $H_{1,2}$ = 8.4 Hz, $J_{2,3}$ = 11.7 Hz, H-2c), 5.46 (d, 1H, $J_{3,4}$ = 3.5 Hz, H-4c), 5.66 (d, 1H, H-1c), 6.17 (dd, 1H, H-3c), and 7.14-7.98 (m, 34H, 7Ph).

Anal. Calcd for $C_{97}H_{112}N_2O_{32}Si$ (1846.0): C, 63.11; H, 6.12; N, 1.52. Found: C, 62.86; H, 6.08; N, 1.61.

2-(Trimethylsilyl)ethyl *O*-(3,4-Di-*O*-acetyl-6-*O*-benzoyl-2-deoxy-2-phthalimido-β-D-galactopyranosyl)-(1→4)-*O*-[(5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonic acid)-(2→3)]-*O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (15). To a solution of **14** (170 mg, 0.09 mmol) in pyridine (8 mL) was added lithium iodide (62 mg), and the mixture was refluxed for 8 h with stirring, under nitrogen atmosphere in the dark, and concentrated and then extracted with dichloromethane. The extract was successively washed with 2M hydrochloric acid and water, dried (Na_2SO_4) and concentrated. Column chromatography (20:1 dichloromethane-methanol) of the residue on silica gel (30 g) gave **15** (134 mg, 80%) as an amorphous mass: $[\alpha]_D$ +3.7° (*c* 0.38, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.03 (m, 2H, $Me_3SiCH_2CH_2$), 1.80 (3), 1.90 (2), 2.02, 2.22 (7s, 21H, AcN, 6AcO), 4.68 (dd, 1H, $J_{1,2}$ = 11.4 Hz, $J_{2,3}$ = 8.4 Hz, H-2a), 4.85 (dd, 1H, $J_{1,2}$ = 9.5 Hz, $J_{2,3}$ = 7.7 Hz, H-2b), 4.95 (d, 1H, H-1a), 5.19 (d, 1H, H-1b), and 6.92-8.20 (m, 34H, 7Ph).

Anal. Calcd for $C_{96}H_{110}N_2O_{32}Si$ (1832.0): C, 62.94; H, 6.05; N, 1.53. Found: C, 62.74; H, 6.24; N, 1.45.

2-(Trimethylsilyl)ethyl *O*-(2-Acetamido-3,4-di-*O*-acetyl-6-*O*-benzoyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-*O*-[(methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)]-*O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (16). A solution of **15** (271 mg, 0.15 mmol) in ethanol (8 mL) was treated with hydrazine hydrate (0.14 mL) for 6 h under reflux. The precipitate was collected and washed with ethanol, and the combined filtrate and washings were concentrated. The residue was treated with acetic anhydride (2 mL)-pyridine (3 mL) for 24 h at room temperature, concentrated, and a solution of the residue in dichloromethane (50 mL) was washed with 2 M hydrochloric acid and water, dried (Na_2SO_4) then concentrated. To a solution of the residue in methanol (3 mL) and diethyl ether (1 mL) was added large excess of diazomethane in diethyl ether at room temperature. After completion of the reaction, acetic acid (0.2 mL) was added, and concentrated to a syrup which was chromatographed on a column of silica gel (40 g) with 30:1 toluene-methanol to give **16** (174 mg, 80%) as an amorphous mass: $[\alpha]_D$ -36.5° (*c* 0.3, $CHCl_3$); ^1H NMR ($CDCl_3$) δ

1.02 (m, 2H, $Me_3SiCH_2CH_2$), 1.83, 1.89 (2), 1.91, 1.96, 1.99, 2.08, 2.18 (8s, 24H, 2AcN, 6AcO), 3.90 (s, 3H, MeO), 5.53 (d, 1H, $J_{3,4}$ = 3.3 Hz, H-3c), and 7.18-7.98 (m, 30H, 6Ph).

Anal. Calcd for $C_{91}H_{112}N_2O_{31}Si$ (1758.0): C, 62.17; H, 6.42; N, 1.59. Found: C, 62.13; H, 6.56; N, 1.56.

2- (Trimethylsilyl) ethyl *O*-(2-Acetamido-3,4-di-*O*-acetyl-6-*O*-benzoyl-2-deoxy-β-D-galactopyranosyl) -(1→4)-*O*-[(methyl 5-acetamido - 4,7,8,9- tetra-*O*-acetyl-3,5-dideoxy -D *-glycero* -α-D-*galacto* - 2- nonulopyranosylonate)-(2→3)]-*O*- (2,6-di-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-β-D-glucopyranoside (17). A solution of **16** (163 mg, 0.1 mmol) in ethanol (30 mL) and acetic acid (10 mL) was hydrogenolysed in the presence of 10% Pd-C (200 mg) for 24 h at 45 °C, then filtered, and concentrated. The residue was treated with acetic anhydride (1.5 mL) and pyridine (2 mL) for 2 days at room temperature. Column chromatography (35:1 dichloromethane-methanol) of the product on silica gel (30 g) gave **17** (133 mg, 95%) as an amorphous mass: $[\alpha]_D$ -22.2° (*c* 0.46, $CHCl_3$); IR (KBr) 3300 (NH), 1750 and 1220 (ester), 1640 and 1540 (amide), 860 and 840 (TMS), and 730 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) δ 0.93 (m, 2H, $Me_3SiCH_2CH_2$), 1.85-2.21 (13s, 39H, 2AcN, 11AcO), 2.84 (dd, 1H, Jgem = 12.9 Hz, $J_{3eq,4}$ = 4.4 Hz, H-3d-eq), 3.33 (dt, 1H, $J_{1,2}$ = 8.0 Hz, $J_{2,3}$ = 11.2 Hz, $J_{2,NH}$ = 7.3 Hz, H-2c), 3.77 (s, 3H, MeO), 4.46 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1a), 4.59 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1b), 4.80 (m, 1H, H-4d), 4.91 (dd, 1H, $J_{2,3}$ = 9.7 Hz, H-2b), 5.00 (dd, 1H, $J_{2,3}$ = 9.9 Hz, H-2a), 5.48 (d, 1H, $J_{3,4}$ = 3.5 Hz, H-4c), 5.52 (m, 1H, H-8d), 5.59 (dd, 1H, H-4c), and 7.29-7.96 (m, 5H, Ph).

Anal. Calcd for $C_{66}H_{92}N_2O_{36}Si$ (1517.5): C, 52.23 H, 6.11; N, 1.85. Found: C, 52.05; H, 6.33; N, 1.74.

***O*-(2-Acetamido -3,4-di-*O*-acetyl-6-*O*-benzoyl-2-deoxy-β- D-galactopyranosyl)-(1→4) -*O*-[(methyl 5- acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)]-*O*-(2,6-di-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-D-glucopyranose (18).** To a solution of **17** (90 mg, 0.06 mmol) in dichloromethane (0.4 mL) was added trifluoroacetic acid (1.0 mL), and the mixture was stirred for 90 min at room temperature then concentrated. Column chromatography (20:1 dichloromethane-methanol) of the residue on silica gel (20 g) gave **18** (81 mg, quantitative): $[\alpha]_D$ -32.0° (*c* 0.3, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.86-2.21 (13s, 39H, 2AcN, 11AcO), 2.86 (dd, 1H, Jgem = 13.3 Hz, $J_{3eq,4}$ = 4.7 Hz, H-3d-eq), 4.58 (dd, 1H, $J_{1,2}$ = 7.8 Hz, H-1b), 5.00 (dd, 1H, $J_{2,3}$ = 10.1 Hz, H-2b), 5.97 (dd, 1H, $J_{2,3}$ = 11.2 Hz, $J_{3,4}$ = 3.4 Hz, H-3c), and 7.28-7.98 (m, 5H, Ph).

Anal. Calcd for $C_{61}H_{80}N_2O_{36}$ (1417.3): C, 51.70; H, 5.69; N, 1.98. Found: C, 51.58; H, 6.77; N, 1.99.

***O*- (2-Acetamido-3,4-di-*O*-acetyl-6-*O*-benzoyl -2-deoxy-β-D-galactopyranosyl)-(1→4) -*O*- [(methyl 5-acetamido - 4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)]-*O*-(2,6-di-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-α-D-glucopyranosyl trichloroacetimidate (19).** To a solution of **18** (136 mg, 0.1 mmol) in dichloromethane (1.5 mL) and trichloroacetonitrile (0.31 mL) cooled to -5 °C was added 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU, 12 mg), and the mixture was stirred for 3 h at 0 °C. Column chromatography (25:1 dichloromethane-methanol) of the mixture on silica gel (30 g) afforded **19** (126 mg, 84%) as an amorphous mass: $[\alpha]_D$ +13.7° (*c* 0.36, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.73 (t, 1H, Jgem = $J_{3ax,4}$ = 12.7 Hz, H-3d-*ax*), 1.85-2.21 (13s, 39H, 2AcN, 11AcO), 2.85 (dd, 1H, $J_{3eq,4}$ = 3.7 Hz, H-3d-eq), 3.30 (dt, 1H, $J_{1,2}$ = 7.8 Hz, $J_{2,3}$ = 11.1 Hz, $J_{2,NH}$ = 7.4 Hz, H-2c), 4.35 (dd, 1H, Jgem = 12.9 Hz, $J_{8,9}$ = 2.7 Hz, H-9d), 4.61 (d, 1H, $J_{1,2}$ = 7.9 Hz, H-1b), 4.83 (m, 1H, H-4d), 5.02 (dd, 1H, $J_{2,3}$ = 10.0 Hz, H-2b), 5.08 (dd, 1H, $J_{1,2}$ = 3.8 Hz, $J_{2,3}$ = 10.2 Hz, H-2a), 5.94 (dd, 1H, $J_{3,4}$ = 3.5 Hz, H-3c), 6.50 (d, 1H, H-1a), 7.16-7.97 (m, 5H, Ph), and 8.66 (s, 1H, C=NH).

Anal. Calcd for $C_{63}H_{80}N_3O_{36}Cl_3$ (1561.7): C, 48.45; H, 5.16; N, 2.69. Found: C, 48.75; H, 5.28; N, 2.53.

***O*- (2-Acetamido-3,4-di-*O*-acetyl-6-*O*-benzoyl-2-deoxy-β-D-galactopyranosyl)-(1→4) -*O*-[(methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)]-*O*-(2,6-di-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-*O*- (2,3,6-tri-*O*-acetyl-β-D-glucopyranosyl)-(1→1)-(2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol (21).** To a solution of **19** (52 mg, 0.03 mmol) and (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol[22] (**20**; 57.2 mg, 0.13 mmol) in dichloromethane (1.0 mL) were added powdered molecular sieves 4Å (AW-300, 200 mg) and the mixture was stirred for 3 h at room temperature and then cooled to 0 °C. Trimethylsilyl trifluoromethanesulfonate (13 μL, 0.07 mmol) was added, and the mixture was stirred for 24 h at 0 °C then filtered. The insoluble material was washed with dichloromethane, and the combined filtrate and washings were washed with M sodium carbonate and water, dried (Na_2SO_4) and concentrated. Column chromatography (30:1 dichloromethane-methanol) of the residue on silica gel (20 g) gave **21** (25 mg, 41%) as an amorphous mass: $[\alpha]_D$ -19.0° (*c* 0.75, $CHCl_3$); IR (KBr) 3300 (NH), 2940 and 2850 (methyl, methylene), 2100 (N_3), 1740 and 1230 (ester), 1660 and 1530 (amide), and 720 cm^{-1} (Ph); ^1H NMR ($CDCl_3$) δ 1.12 (t, 3H, *Me*CH_2), 1.24 (s, 22H, 11CH_2), 1.73 (t, 1H, Jgem = $J_{3ax,4}$ = 12.7 Hz, H-3d-*ax*), 1.86-2.21 (13s, 39H, 2AcN, 11AcO), 2.85 (dd, 1H, $J_{3eq,4}$ = 4.4 Hz, H-3d-*eq*), 4.49 (d, 1H, $J_{1,2}$ = 7.8 Hz, H-1a), 4.59 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1b), 4.96 (dd, 1H, $J_{2,3}$ = 9.5 Hz, H-2a), 4.99 (dd, 1H, $J_{2,3}$ = 9.6 Hz, H-2b), and 7.42-8.05 (m, 10H, 2Ph).

Anal. Calcd for $C_{86}H_{117}N_5O_{38}$ (1796.8): C, 57.48; H, 6.56; N, 3.90. Found: C, 57.45; H, 6.66; N, 3.78.

***O*-(2-Acetamido-3,4-di-*O*-acetyl-6-*O*-benzoyl-2-deoxy-β-D-galactopyranosyl)-(1→4) -*O*-[(methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→3)]-*O*-(2,6-di-*O*-acetyl-β-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-D-glucopyranosyl)-(1→1)-(2*S*,3*R*,4*E*)-3-*O*-benzoyl-2-octadecanamido-4-octadecene-1,3-diol (22).** Hydrogen sulfide was bubbled through a stirred solution of **21** (37.4 mg, 0.02 mmol) in aqueous 83% pyridine (4.8 mL) for 48 h at 0 °C. The reaction was monitored by TLC. After completion of the reaction, the mixture was concentrated, and the residue was stirred with octadecanoic acid (13 mg, 0.04 mmol) and 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (13 mg, 0.06 mmol) in dry dichloromethane (1.5 mL) for 12 h at room temperature. Column chromatography (30:1 dichloromethane-methanol) of the mixture on silica gel (20 g) gave **22** (31.3 mg, 73%) as an amorphous mass: $[\alpha]_D$ -10.3° (*c* 0.62, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.88 (t, 6H, 2*Me*CH_2), 1.25 (s, 52H, 26CH_2), 1.73 (t, 1H, Jgem = $J_{3ax,4}$ = 13.0 Hz, H-3d-*ax*), 1.86-2.18 (13s, 39H, 2AcN, 11AcO), 2.84 (dd, 1H, $J_{3eq,4}$ = 4.1 Hz, H-3d-*eq*), 4.33 (d, 1H, $J_{1,2}$ = 8.0 Hz, H-1a), 4.56 (d, 1H, $J_{1,2}$ = 7.5 Hz, H-1b), 4.93 (dd, 1H, $J_{2,3}$ = 9.7 Hz, H-2a), 4.97 (dd, 1H, $J_{2,3}$ = 10.0 Hz, H-2b), and 7.40-8.01 (m, 10H, 2Ph).

Anal. Calcd for $C_{104}H_{153}N_3O_{39}$ (2069.4): C, 60.36; H, 7.45; N, 2.03. Found: C, 60.22; H, 7.61; N, 1.94.

Ganglioside GM_2 (23). To a solution of **22** (31.2 mg, 0.015 mmol) in methanol (3 mL) was added sodium methoxide (10 mg), the mixture was stirred for 24 h at room temperature, and 0.2 M potassium hydroxide (0.7 mL) was added. The solution was stirred for 24 h at room temperature, neutralized with Amberlite IR-120 (H^+) resin, and filtered, the resin was washed with 1:1 chloroform-methanol, and the combined filtrate and washings were concentrated. Column chromatography (1:1 chloroform-methanol) of the residue on Sephadex LH-20 (20 g) gave **23** (20.5 mg, quantitative) as an amorphous mass: $[\alpha]_D$ +11.3° (*c* 0.48, 1:1 $CHCl_3$ - MeOH); ^1H NMR [98:2 $(CD_3)_2SO$-D_2O] δ 0.90 (t, 6H, 2*Me*CH_2), 1.28 (s, 50H, 25CH_2), 1.86, 1.95 (2s, 6H, 2AcN), 4.24 (d, 1H, $J_{1,2}$ = 7.3 Hz, H-1a), 4.38 (d, 1H, $J_{1,2}$ = 7.0 Hz, H-1b), 4.83 (d, 1H, $J_{1,2}$ = 7.3 Hz, H-1c), 5.38 (dd, 1H, $J_{3,4}$ = 6.1 Hz, $J_{4,5}$ = 14.6 Hz, H-4 for ceramide), and 5.57 (m, 1H, $J_{5,6}$ = $J_{5,6'}$ = 6.5 Hz, H-5 for ceramide).

Anal. Calcd for $C_{67}H_{121}N_3O_{26}$ (1372.7): C, 57.74; H, 8.89; N, 3.06. Found: C, 57.55; H, 9.05; N, 3.16.

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