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Regio- and stereo-selective synthesis of ganglioside GM1b and some positional analogs*,†

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ABSTRACT

Total syntheses of ganglioside GM1b (IV^{3}NeuAcGgOse$_4$Cer) and three of its positional analogs are described. 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 (**7**) and methyl *O*-(methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2→6)-2,4-di-*O*-benzoyl-3-*O*-benzyl-1-thio-β-D-galactopyranoside (**8**) were the key glycosyl donors, prepared according to our reported methods. Coupling of 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-α-D-galactopyranosyl bromide and 2-(trimethylsilyl)ethyl *O*-(2,3,6-tri-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside gave a trisaccharide, which after removal of *O*-acetyl and phthaloyl groups was converted separately, by benzylidenation and dibutyltin oxide-mediated selective benzylation, into two glycosyl acceptors. These were suitable respectively for C-3 and C-6 glycosylation reactions, promoted by dimethyl(methylthio)sulfonium triflate (DMTST), with the donors **7** and **8**. The four possible coupling reactions gave the corresponding four pentasaccharide derivatives in high yields, and these were transformed into their respective α-trichloroacetimidates. Glycosylation of (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol with the α-trichloroacetimidates gave the corresponding β-glycosides, which on channeling through selective reduction of the azido group, coupling of the thus formed amino group with octadecanoic acid, *O*-deacetylation, and saponification of the methyl ester group, gave the title compounds.

INTRODUCTION

The literature[2] on the isolation and characterization of various gangliosides from normal and pathogenic tissues has amply demonstrated their involvement as modulators in various biological phenomena. The occurrence of structurally diverse gangliosides, in accordance with the nature of the tissue, strongly indicates that their spatial and molecular nature play an important role. However, the specific structure to function relations of these cell membrane components have not been deciphered. The occurrence of ganglioside GM1b was first demonstrated by Yip[3], who isolated it from rat brain. Later it was biosynthesized *in vitro* and its structure was established as IV^{3}NeuAcGgOse$_4$Cer (ref. 4). Since then this ganglioside has been recognized in rat ascites hepatoma[5]

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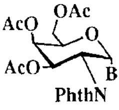
and bone marrow[6], mouse meyloid leukemia[7], spleen,[8] and lymphocytes[9], human erythrocyte membrane[10] and brain[11], and adult bovine brain[12].

The development of regio- and stereo-selective synthetic approaches for procuring various gangliosides has been an attractive goal for carbohydrate chemists, as most of the gangliosides are not very abundant in biological sources. Our past efforts in this regard have resulted in the development of a facile method for the stereoselective α-glycosidation[13] of sialic acid with suitably protected galactose and lactose acceptors, employing dimethyl(methylthio)sulfonium triflate (DMTST) as the glycosidation promoter in acetonitrile. This method has subsequently served us for the successful synthesis of several gangliosides and their analogs[14]. Here we report the regio- and stereo-selective synthesis of ganglioside GM1b and three of its positional analogs.

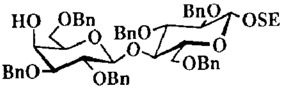
RESULTS AND DISCUSSION

The glycosyl donors **7** and **8**, required for the synthesis of ganglioside GM1b and its three positional analogs, were prepared according to our reported methods[14f,14j]. Suitably protected trisaccharides, *viz.* 2-(trimethylsilyl)ethyl *O*-(2-acetamido-4,6-*O*-benzylidene-2-deoxy-β-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (**5**) and 2-(trimethylsilyl)ethyl *O*-(2-acetamido-3-*O*-benzyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-O-*benzyl-β*-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (**6**) were designed as glycosyl acceptors. Coupling of 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-α-D-galactopyranosyl bromide[14a] (**1**) and 2-(trimethylsilyl)ethyl *O*-(2,3,6-tri-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside[15] (**2**) by the Koenigs–Knorr method gave 82% of the trisaccharide (**3**). The stereochemistry at the newly formed glycosidic bond was established as β by ^{1}H-n.m.r., which showed a doublet at δ 5.34 ($J_{1,2}$ 8.4 Hz). Treatment of compound **3** with hydrazine monohydrate, followed by *N*-acetylation, afforded the acetamido derivative **4**, which was converted into the two glycosyl acceptors by separate reactions. Firstly, *p*-toluenesulfonic acid-catalyzed benzylidenation gave a 77% yield of **5**, having a free hydroxyl group at C-3, and secondly, dibutyltin oxide-mediated[16] selective benzylation gave a 72% yield of **6**, which was used for glycosylation at the 6-position.

Individual glycosylations, with the four possible combinations of two trisaccharide acceptors and two disaccharide donors, were performed in the presence of DMTST in dichloromethane for 12–20 h at 0°. The isolated yields of the respective pentasaccharides **10A–13A** were in the range of 67–73%. The ^{1}H-n.m.r. spectra of these compounds contained signals appropriate to the structures assigned, including a doublet around δ 4.8 ($J_{1,2}$ 7–8 Hz) due to the newly formed β-glycosidic linkages. Hydrogenolytic cleavage of the benzyl groups in these intermediates, catalyzed by 10% Pd–C in 8:1 ethanol–acetic acid, followed by hydrolysis of the benzylidene group (in the case of **10B** and **12B**) and acetylation gave the respective oligosaccharide derivatives **10B–13B** in moderate yields. Further, selective removal of the 2-(trimethyl)ethyl group from **10B–13B**, by treatment with either boron trifluoride etherate (12 h at 0°) or trifluoroacetic acid (2 h at



1



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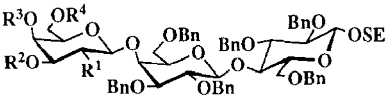
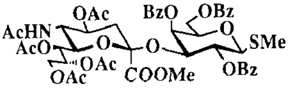


3 R^1= NPhth, R^2= R^3= R^4= Ac
4 R^1= NHAc, R^2= R^3= R^4= H
5 R^1= NHAc, R^2= H, R^3-R^4= CHPh
6 R^1= NHAc, R^2= Bn, R^3= R^4= H



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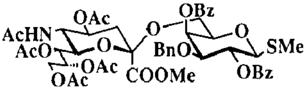

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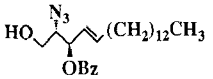


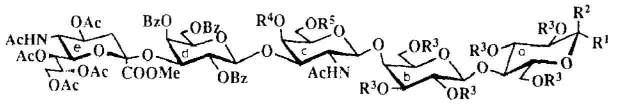
9

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

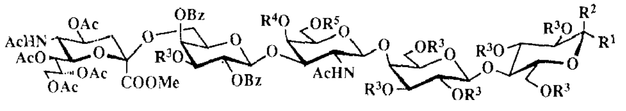
room temperature) in dichloromethane, gave the respective 1-hydroxy compounds **10C**–**13C** in high yields. These on treatment[17] with trichloroacetonitrile, in the presence of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) in dichloromethane for 4 h at 0°, afforded the trichloroacetimidates **10D**–**13D**. The ^{1}H-n.m.r. spectra of these compounds showed signals at δ ~6.45 (d, 1 H, $J_{1a,2a}$ ~3.66 Hz, H-1a) and ~8.65 (s, 1 H, C=N*H*), signifying that the trichloroacetimidates were α anomers.

The glycosylation[17a,18] of (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol[19] (**9**) could be effected with either boron trifluoride etherate or trimethylsilyl trifluoromethanesulfonate as promoter. Thus, compounds **10D** and **12D** were treated with two molar equivalents of **9**, in the presence of boron trifluoride etherate in dichloromethane, to afford the corresponding β glycosides **10E** and **12E** in 62 and 51% yields, respectively. Compounds **11D** and **13D**, on the other hand, were treated similarly with **9**, except that trimethylsilyl trifluoromethanesulfonate was used as the glycosylation promoter, to get β glycosides **11E** and **13E** in 62 and 72% yields, respectively. Aqueous 83% pyridine solutions of these compounds were submitted to hydrogen sulfide bubbling for 48 h at 0–15°, for selective reduction[20] of the azido group to give the corresponding amines **10F**–**13F**, which were subsequently condensed with octadecanoic acid, in the presence of 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (WSC) in dichloromethane, to give the corresponding fully protected gangliosides **10G**–**13G** in high yields.

O-Deacylation with sodium methoxide in methanol and subsequent saponification of the methyl ester group in **10G**–**13G** afforded ganglioside GM1b (**10H**) and the analogous compounds **11H**–**13H** in high yields. The ^{1}H-n.m.r. spectra of ganglioside GM1b and its analogs were in good agreement with the spectrum reported by Ariga and Yu[11].

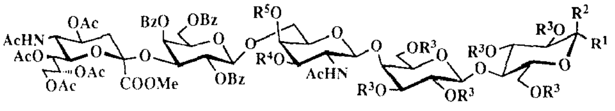


10A-10D

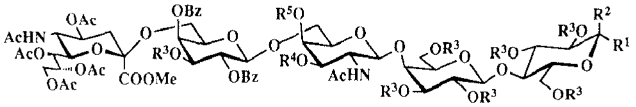


11A-11D

10A, 11A R^1= OSE, R^2= H, R^3= Bn, R^4-R^5= CHPh
10B, 11B R^1= OSE, R^2= H, R^3= R^4= R^5= OAc
10C, 11C R^1, R^2= H, OH, R^3= R^4= R^5= OAc
10D, 11D R^1= H, R^2= OC(=NH)CCl$_3$, R^3= R^4= R^5= OAc

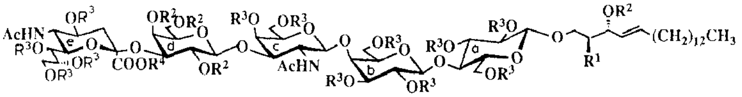


12A-12D

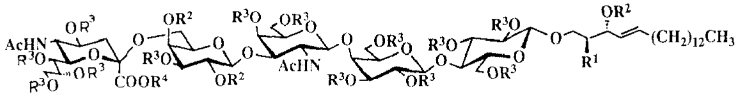


13A-13D

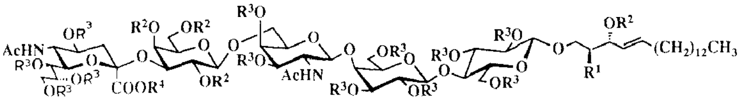
12A, 13A R^1= OSE, R^2= H, R^3= R^4= Bn, R^5= H
12B, 13B R^1= OSE, R^2= H, R^3= R^4= R^5= OAc
12C, 13C R^1, R^2= H, OH, R^3= R^4= R^5= OAc
12D, 13D R^1= H, R^2= OC(=NH)CCl$_3$, R^3= R^4= R^5= OAc



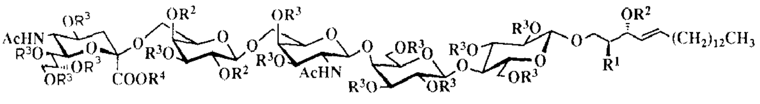
10E-10H



11E-11H



12E-12H



13E-13H

10E, 11E, 12E, 13E R^1= N$_3$, R^2= Bz, R^3= Ac, R^4= Me
10F, 12F, 12F, 13F R^1= NH$_2$, R^2= Bz, R^3= Ac, R^4= Me
10G, 11G, 12G, 13G R^1= NHCO(CH$_2$)$_{16}$CH$_3$, R^2= Bz, R^3= Ac, R^4= Me
10H, 11H, 12H, 13H R^1= NHCO(CH$_2$)$_{16}$CH$_3$, R^2= R^3= R^4= H

The synthetic work described above demonstrates the profound efficacy of DMTST as a promoter for introducing β-linkages, assisted anchimerically at C-2, in the construction of pentasaccharides, in addition to its efficacy, reported earlier, in the synthesis of predominantly alpha sialyl glycosides. Also, the use of the 2-(trimethylsilyl)ethyl group for protecting the anomeric hydroxyl group, and the high yielding reactions for coupling the ceramide to the oligosaccharide moiety, make this the best practical scheme for the synthesis of complex sialoglycoconjugates.

EXPERIMENTAL

General methods. — Specific rotations were determined with a Union PM-201 polarimeter at 25° and i.r. spectra were recorded with a Jasco IRA-100 spectrophotometer. ^{1}H-N.m.r. spectra were recorded with a JEOL JNM-GX270 spectrometer. Preparative chromatography was performed on silica gel (Wako Co., 200 mesh) with the solvents specified. Evaporations were conducted *in vacuo*.

*2-(Trimethylsilyl)ethyl O-(3,4,6-tri-O-acetyl-2-deoxy-2-phthalimido-β-*D*-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-benzyl-β-*D*-galactopyranosyl)-(1→4)-O-2,3,6-tri-O-benzyl-β-*D*-glucopyranoside* (**3**). — A mixture (*A*) of 2-(trimethylsilyl)ethyl *O*-(2,3,6-tri-*O*-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside[15](**2**, 2.1 g, 2.1 mmol), silver carbonate (656 mg, 2.4 mmol), silver perchlorate (528 mg, 2.5 mmol), and powdered molecular sieves 4A (2.2 g) in dichloromethane (10 mL) was stirred in the dark for 8 h at room temperature. Simultaneously, a mixture of 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-α-D-galactopyranosyl bromide[14a] (**1**, 1.2 g, 2.4 mmol) and molecular sieves 4A (1 g) in dichloromethane was stirred for 8 h at room temperature, then added to mixture *A*. After the combined reaction mixture was stirred in the dark for 9 h at room temperature, insolubles were filtered off and washed with dichloromethane, and the combined filtrate and washings was concentrated. Column chromatography (8:2 hexane–ethyl acetate) of the residue on silica gel (150 g) gave amorphous **3** (2.39 g, 82%), $[\alpha]_D$ +4.1° (c 0.98, CH_2Cl_2); ν_{max} 1750 and 1230 (ester), 1720 (imide), 860 and 840 (Me_3Si), and 740, 720, and 700 cm^{-1} (Ph); ^{1}H-n.m.r. ($CDCl_3$): δ 0.99 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.83, 1.86, 2.19 (3 s, 9 H, 3 CH_3CO), 4.40 (d, 1 H, $J_{1a,2a}$ 7.0 Hz, H-1a), 4.45 (d, 1 H, $J_{1b,2b}$ 7.3 Hz, H-1b), 4.59 (dd, 1 H, $J_{2c,3c}$ 8.3 Hz, H-2c), 5.34 (d, 1 H, $J_{1c,2c}$ 8.4 Hz, H-1c), 5.53 (d, 1 H, $J_{3c,4c}$ 3.3 Hz, H-4c), 6.11 (dd, 1 H, $J_{2c,3c}$ 8.0, $J_{3c,4c}$ 3.3 Hz, H-3c), and 7.1–7.4 (m, 34 H, 6 Ph and phthaloyl).

Anal. Calc. for $C_{79}H_{89}NO_{20}Si$ (1400.7): C, 67.74; H, 6.40; N, 1.00. Found: C.67.61; H, 6.39; N, 1.02.

*2-(Trimethylsilyl)ethyl O-(2-acetamido-2-deoxy-β-*D*-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-benzyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-O-benzyl-β-*D*-glucopyranoside* (**4**). — A solution of **3** (1.2 g, 0.85 mmol) in 95% ethanol (35 mL) and hydrazine monohydrate (6 mL) was heated for 3 h under reflux. After cooling, insolubles were filtered off and washed with ethanol. The filtrate and washings were combined and evaporated to dryness, the residue was treated with acetic anhydride (5 mL) and methanol (30 mL) for 8 h at room temperature, and the solution was concentrated.

Column chromatography (50:1 dichloromethane–methanol) of the residue on silica gel (100 g) gave amorphous **4** (722 mg, 69%), $[\alpha]_D$ +58.3° (*c* 0.84, CH_2Cl_2); ν_{max} 3400 (NH and OH), 1680 and 1540 (amide), 860 and 840 (Me_3Si), and 740, 720, and 700 cm^{-1} (Ph); ^{1}H-n.m.r. ($CDCl_3$): δ 0.99 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.57 (s, 3 H, $NCOCH_3$), and 7.1–7.4 (m, 30 H, 6 Ph).

Anal. Calc. for $C_{67}H_{83}NO_{16}Si$ (1186.5): C, 67.82; H, 7.05; N, 1.18. Found: C, 67.70; H, 7.12; N, 1.19.

2-(Trimethylsilyl)ethyl O-*(2-acetamido-4,6-*O-*benzylidene-2-deoxy-β-*D-*galactopyranosyl)-(1→4)-*O-*(2,3,6-tri-*O-*benzyl-β-*D-*galactopyranosyl)-(1→4)-2,3,6-tri-*O-*benzyl-β-*D-*glucopyranoside* (**5**). — A solution of **4** (750 mg, 0.63 mmol) in dry *N,N*-dimethylformamide (5 mL) was stirred with benzaldehyde dimethyl acetal (0.23 mL, 1.5 mmol) and a catalytic amount of *p*-toluenesulfonic acid monohydrate for 12 h at room temperature. After the addition of triethylamine (1 mL), the mixture was concentrated. Column chromatography (6:4 hexane–ethyl acetate) of the residue on silica gel (80 g) gave amorphous **5** (620 mg, 77%), $[\alpha]_D$ +24° (*c* 1.2, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 1.0 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.59 (s, 3 H, $NCOCH_3$), 5.57 (s, 1 H, CHPh), and 7.1–7.4 (m, 35 H, 7 Ph).

Anal. Calc. for $C_{74}H_{87}NO_{16}Si$ (1274.6): C, 69.73; H, 6.87; N, 1.09. Found: C, 69.65; H, 6.90, N, 1.12.

2-(Trimethylsilyl)ethyl O-*(2-acetamido-3-*O*-benzyl-2-deoxy-β-*D-*galactopyranosyl)-(1→4)-*O-*(2,3,6-tri-*O*-benzyl-β-*D-*galactopyranosyl)-(1→4)-2,3,6-tri-*O-*benzyl-β-*D-*glucopyranoside* (**6**). — A mixture of **4** (1 g, 0.84 mmol) and di-*n*-butyltin oxide (800 mg) in methanol (25 mL) was refluxed for 2 h, then concentrated. To a suspension of the residue in dry benzene (15 mL) were added benzyl bromide (0.65 mL) and tetrabutylammonium bromide (600 mg) and the mixture was heated at 80° for 4 h, then concentrated. Column chromatography (1:1 hexane–ethyl acetate) of the residue on silica gel (100 g) gave **6** (790 mg, 72%), isolated as a syrup, $[\alpha]_D$ +28.5° (*c*, 0.54, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 0.99 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.71 (s, 3 H, $NCOCH_3$), and 7.1–7.4 (m, 35 H, 7 Ph).

Anal. Calc. for $C_{74}H_{89}NO_{16}Si$ (1276.5): C, 69.68; H, 7.02; N, 1.09. Found: C, 69.59; H, 7.05; N, 1.06.

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-*O-*benzylidene-2-deoxy-β-*D-*galactopyranosyl)-(1→4)-*O-*(2,3,6-tri-*O-*benzyl-β-*D-*galactopyranosyl)-(1→4)-2,3,6-tri-*O-*benzyl-β-*D-*glucopyranoside* (**10A**). — To a solution of **5** (620 mg, 0.48 mmol) and **7** (ref. 14f, 553 mg, 0.56 mmol) in dichloromethane (15 mL) was added powdered molecular sieves 4A (1.2 g), and the mixture was stirred for 8 h at room temperature, then cooled to 0°. A mixture of DMTST (673 mg, 2.6 mmol) and molecular sieves 4A (300 mg) was added and the reaction was monitored by t.l.c. while the mixture was stirred at 0°. After 12 h the solids were filtered off and washed with dichloromethane, and the combined filtrate and washings was washed with M sodium hydrogencarbonate and water, dried (Na_2SO_4), and concentrated. Column chromatography (100:2 dichloromethane–methanol) of the residue on silica gel (50 g) gave amorphous **10A** (792 mg, 73%), $[\alpha]_D$ +31.6° (*c* 1.1, CH_2Cl_2); ν_{max} 3400 (NH), 1740 and 1230 (ester), 1680 and 1540 (amide), 860 and 840 (Me_3Si), and 740 and 720 cm^{-1} (Ph); ^{1}H-n.m.r. ($CDCl_3$): δ 1.0 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.32, 1.52 (2 s, 6 H, 2 $NCOCH_3$), 1.59 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e}$ = 12.8 Hz, H-3e-*ax*), 1.74, 1.88, 2.07, 2.16 (4 s, 12 H, 4 $OCOCH_3$), 2.41 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.80 (s, 3 H, CH_3O), 4.84 (d, 1 H, $J_{1d,2d}$ 8.0 Hz, H-1d), 5.05 (d, 1 H, $J_{NH,5e}$ 8.6 Hz, N*H*-e), 5.33 (d, 1 H, $J_{3d,4d}$ 2.9 Hz, H-4d), 5.40 (s, 1 H, C*H*Ph), 5.44 (dd, 1 H, $J_{1d,2d}$ = $J_{2d,3d}$ = 7.7 Hz, H-2d), 5.57 (m, 1 H, H-8e), and 7.18–8.17 (m, 50 H, 10 Ph).

Anal. Calc. for $C_{121}H_{136}N_2O_{36}Si$ (2222.5): C, 65.39; H, 6.16; N, 1.26. Found: C, 65.32; H, 6.26; N, 1.29.

*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-(2,3,6-tri-O-acetyl-β-*D-*galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-β-*D-*glucopyranoside* (**10B**). — A suspension of **10A** (424 mg, 0.19 mmol) in ethanol–acetic acid (8:1, 80 mL) was hydrogenolyzed in the presence of 10% Pd–C (660 mg) for 2 days at 50° then filtered, and the insolubles were washed with ethanol. The filtrate and washings were combined and concentrated. A solution of the residue in aqueous 80% acetic acid (40 mL) was heated at 45° for 24 h, then concentrated. The residue was acetylated with acetic anhydride (2 mL) in pyridine (3 mL) at 45° for 24 h. Methanol (1 mL) was added to the mixture and it was concentrated. Column chromatography (100:2 dichloromethane–methanol) of the residue on silica gel (40 g) gave amorphous **10B** (218 mg, 59%), $[\alpha]_D$ +14.3° (*c* 0.92, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 1.0 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.53, 1.56 (2 s, 6 H, 2 $NCOCH_3$), 1.60 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e}$ = 12.8 Hz, H-3e-*ax*), 1.74–2.16 (12 s, 36 H, 12 $OCOCH_3$), 2.41 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.81 (s, 3 H, CH_3O), 4.88 (d, 1 H, $J_{1d,2d}$ 7.7 Hz, H-1d), 5.19 (dd, 1 H, $J_{6e,7e}$ 2.9, $J_{7e,8e}$ 9.16 Hz, H-7e), 5.36 (d, 1 H, $J_{3d,4d}$ 2.9 Hz, H-4d), 5.58 (m, 1 H, H-8e), and 7.4–8.2 (m, 15 H, 3 Ph).

Anal. Calc. for $C_{88}H_{112}N_2O_{44}Si$ (1929.9): C, 54.76; H, 5.84; N, 1.45. Found: C, 54.66; H, 5.84; N, 1.43

*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-(2,3,6-tri-O-acetyl-β-*D-*galactopyranosyl-(1→4)-2,3,6-tri-O-acetyl-*D-*glucopyranose* (**10C**). — To a solution of **10B** (218 mg, 0.11 mmol) in dichloromethane (2 mL) was added trifluoroacetic acid (0.8 mL). The mixture was stirred for 2 h at room temperature, then concentrated. Column chromatography (100:2 dichloromethane–methanol) of the residue on silica gel (30 g) gave amorphous **10C** (175 mg, 85%), $[\alpha]_D$ +33° (*c* 0.84, CH_2Cl_2); ν_{max} 3400 (NH, OH), 1740 and 1230 (ester), 1670 and 1540 (amide), and 720 cm^{-1} (Ph).

Anal. Calc. for $C_{83}H_{100}N_2O_{44}$ (1829.7): C, 54.48; H, 5.50; N, 1.53. Found: C, 54.39; H, 5.46; N, 1.50.

*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-(2,3,6-tri-O-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-α-*D*-glucopyranosyl trichloroacetimidate* (**10D**). — To a solution of **10C** (166 mg, 0.090 mmol) in dichloromethane (2 mL) and trichloroacetonitrile (0.3 mL) was added 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU, 0.05 mL) at 0°, and the mixture was stirred for 4 h at 0°, then concentrated. Column chromatography (100:2 dichloromethane–methanol) of the residue on silica gel (30 g) gave amorphous **10D** (149 mg, 83%), $[\alpha]_D$ +41.7° (*c* 0.44, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 1.53, 1.56 (2 s, 6 H, 2 NCOCH_3), 1.60 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e}$ 12.8 Hz, H-3e-*ax*), 1.74–2.16 (12 s, 36 H, 12 OCOCH_3), 2.41 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.81 (s, 3 H, CH_3O), 5.19 (dd, 1 H, $J_{6e,7e}$ 2.9, $J_{7e,8e}$ 9.16 Hz, H-7e), 5.36 (d, 1 H, $J_{3d,4d}$ 2.9 Hz, H-4d), 5.58 (m, 1 H, H-8e), 6.48 (d, 1 H, $J_{1a,2a}$ 3.66 Hz, H-1a), 7.4–8.2 (m, 15 H, 3 Ph), and 8.66 (s, 1 H, C=N*H*).

Anal. Calc. for $C_{85}H_{100}Cl_3N_3O_{44}$ (1974.1): C, 51.71; H, 5.10; N, 2.12. Found: C, 51.66; H, 5.14; N, 2.11.

*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→6)-O-(2,4-di-O-benzoyl-3-O-benzyl-β-*D*-galactopyranosyl)-(1→3)-O-(2-acetamido-4,6-O-benzylidene-2-deoxy-β-*D*-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-benzyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-O-benzyl-β-*D*-glucopyranoside* (**11A**). — Glycosylation of **8** (ref. 14j, 656 mg, 0.67 mmol) with **5** (740 mg, 0.58 mmol), as described for **10A**, gave amorphous **11A** (882 mg, 68.5%), $[\alpha]_D$ +34.4° (*c* 0.86, CH_2Cl_2); ν_{max} 3400 (NH), 1740 and 1230 (ester), 1680 and 1540 (amide), 860 and 840 (Me_3Si), and 740 and 720 cm^{-1} (Ph); ^{1}H-n.m.r. ($CDCl_3$): δ 0.98 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.07, 1.85 (2 s, 6 H, 2 NCOCH_3), 1.59 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e}$ 12.8 Hz, H-3e-*ax*), 1.95, 1.99, 2.02, 2.13 (4 s, 12 H, 4 OCOCH_3), 2.50 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.4 Hz, H-3e-*eq*), 3.10 (s, 3 H, CH_3O), 4.80 (d, 1 H, $J_{1d,2d}$ 8.0 Hz, H-1d), 5.07 (d, 1 H, $J_{NH,5e}$ 9.6 Hz, N*H*-e), 5.22 (dd, 1 H, $J_{6e,7e}$ 2.9, $J_{7e,8e}$ 9.16 Hz, H-7e), 5.33 (m, 1 H, H-8e), 5.47 (dd, 1 H, $J_{2d,3d}$ 9.6 Hz, H-2d), 5.77 (s, 1 H, C*H*Ph), 5.88 (d, 1 H, $J_{3d,4d}$ 3.3 Hz, H-4d), and 7.19–8.20 (m, 50 H, 10 Ph).

Anal. Calc. for $C_{121}H_{138}N_2O_{35}Si$ (2208.5): C, 65.81; H, 6.30; N, 1.27. Found: C, 65.75; H, 6.37; N, 1.29.

*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→6)-O-(2,4-di-O-benzoyl-3-O-acetyl-β-*D*-galactopyranosyl)-(1→3)-O-(2-acetamido-4,6-di-O-acetyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-β-*D*-glucopyranoside* (**11B**). — As described for **10B**, a suspension of **11A** (702 mg, 0.32 mmol) in ethanol–acetic acid (8:1, 100 mL) was hydrogenolyzed, treated with aqueous acetic acid, and acetylated to get amorphous **11B** (315 mg, 53%), $[\alpha]_D$ +2.6° (*c* 0.60, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 0.9 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.85, 1.86 (2s, 6 H, 2 NCOCH_3), 1.90–2.21 (13 s, 39 H, 13 OCOCH_3), 2.43 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.4 Hz, H-3e-*eq*), 2.99 (m, 1 H, H-2c), 3.42 (s, 3 H, CH_3O), 4.91 (d, 1 H, $J_{1d,2d}$ 7.7 Hz, H-1d), 5.40 (~dd, 1 H, H-2d), 5.79 (d, 1 H, $J_{3d,4d}$ 3.3 Hz, H-4d), and 7.44–8.15 (m, 10 H, 2 Ph).

Anal. Calc. for $C_{83}H_{110}N_2O_{44}Si$ (1867.9): C, 53.37; H, 5.94; N, 1.50. Found: C, 53.34; H, 6.00; N, 1.48.

O-*(Methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→6)-*O*-(3-*O*-acetyl-2,4-di-*O*-benzoyl-β-*D*-galactopyranosyl)-(1→3)-*O*-(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-β-*D*-glucopyranose* (**11C**). — To a solution of **11B** (258 mg, 0.14 mmol) in dichloromethane (3 mL) was added boron trifluoride etherate (0.2 mL) at 0°. After stirring for 12 h at 0°, more dichloromethane (25 mL) was added. The organic layer was washed with M sodium hydrogencarbonate and water, dried (Na_2SO_4), and concentrated. Column chromatography (100:2 dichloromethane–methanol) of the residue on silica gel (30 g) gave amorphous **11c** (214 mg, 88%), $[\alpha]_D$ +21.8° (*c* 1.04, CH_2Cl_2); ν_{max} 3400 (NH, OH), 1740 and 1230 (ester), 1670 and 1540 (amide), and 720 cm^{-1} (Ph).

Anal. Calc. for $C_{78}H_{98}N_2O_{44}$ (1767.6): C, 53.00; H, 5.59; N, 1.58. Found: C, 52.77; H, 5.61; N, 1.55.

O-*(Methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→6)-*O*-(3-*O*-acetyl-2,4-di-*O*-benzoyl-β-*D*-galactopyranosyl)-(1→3)-*O*-(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-α-*D*-glucopyranosyl trichloroacetimidate* (**11D**). — A solution of **11C** (206 mg, 0.12 mmol) in dichloromethane (3 ml) was treated with trichloroacetonitrile (0.3 mL) in a fashion similar to that described for **10D**, to get amorphous **11D** (194 mg, 88%), $[\alpha]_D$ +26.3° (*c* 0.52, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 1.53, 1.56 (2 s, 6 H, 2 $NCOCH_3$), 1.60 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e}$ = 12.8 Hz, H-3e-*ax*), 1.74–2.16 (13 s, 39 H, 13 $OCOCH_3$), 2.41 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.41 (s, 3 H, CH_3O), 5.19 (dd, 1 H, $J_{6e,7e}$ 2.9, $J_{7e,8e}$ 9.16 Hz, H-7e), 5.36 (d, 1 H, $J_{3d,4d}$ 2.9 Hz, H-4d), 5.58 (m, 1 H, H-8e), and 7.4–8.2 (m, 10 H, 2 Ph).

Anal. Calc. for $C_{80}H_{98}Cl_3N_3O_{44}$ (1912.0): C, 50.25; H, 5.17; N, 2.20. Found: C, 50.21; H, 5.29; N, 2.15.

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→6)-*O*-(2-acetamido-3-*O*-benzyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-benzyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-*D*-glucopyranoside* (**12A**). — Glycosylation of **6** (600 mg, 0.47 mmol) with **7** (452 mg, 0.45 mmol), as described for **10A**, gave amorphous **12A** (692 mg, 66%), $[\alpha]_D$ +37° (*c* 0.54, CH_2Cl_2); ν_{max} 3400–3300 (NH, OH), 1740 and 1230 (ester), 1680 and 1540 (amide), 860 and 840 (Me_3Si), and 740 and 720 cm^{-1} (Ph); ^{1}H-n.m.r. ($CDCl_3$): δ 1.03 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.65, 1.76 (2 s, 6 H, 2 $NCOCH_3$), 1.59 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e}$ = 12.4 Hz, H-3e-*ax*), 1.90, 1.95, 1.99, 2.02, (4 s, 12 H, 4 $OCOCH_3$), 2.50 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.4 Hz, H-3e-*eq*), 3.83 (s, 3 H, CH_3O), 4.80 (d, 1 H, $J_{1d,2d}$ 7.8 Hz, H-1d), 5.18 (d, 1 H, $J_{NH,5e}$ 9.6 Hz, N*H*-e), 5.40 (br. d, 1 H, H-4d), 5.45 (dd, 1 H, H-2d), 5.52 (m, 1 H, H-8e), and 7.15–8.22 (m, 50 H, 10 Ph).

Anal. Calc. for $C_{121}H_{138}N_2O_{36}Si$ (2224.5): C, 65.33; H, 6.25; N, 1.26. Found: C, 65.28; H, 6.21; N, 1.23.

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→6)-*O*-(2-acetamido-3,4-di-*O*-acetyl-2-deoxy-β-*D*-galacto-pyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-β-*D*-glucopyranoside* (**12B**). — A suspension of **12A** (658 mg, 0.29 mmol) in 8:1 ethanol–acetic acid (90 mL) was hydrogenolyzed in the presence of 10% Pd–C (850 mg) for 2 days at 50°. The catalyst was filtered off and washed with ethanol, then the combined filtrate and washings was concentrated. The residue was treated with acetic anhydride (2 mL) and pyridine (4 mL) for 24 h at 45°, then concentrated. Column chromatography (100:2 dichloromethane–methanol) of the residue on silica gel (60 g) gave amorphous **12B** (319 mg, 56%), $[\alpha]_D$ +2.2° (*c* 0.62, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 0.9 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.54, 1.77 (2 s, 6 H, 2 $NCOCH_3$), 1.59 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e}$ = 12.4 Hz, H-3e-*ax*), 1.90–2.14 (12 s, 36 H, 12 $OCOCH_3$), 2.40 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.4 Hz, H-3e-*eq*), 3.18 (m, 1 H, H-2c), 3.82 (s, 3 H, CH_3O), 4.83 (d, 1 H, $J_{1d,2d}$ 8.0 Hz, H-1d), 5.02 (d, 1 H, $J_{1c,2c}$ 8.0 Hz, H-1c), 5.21 (dd, 1 H, $J_{6e,7e}$ 2.9, $J_{7e,8e}$ 9.1 Hz, H-7e), 5.56 (m, 1 H, H-8e), 5.77 (dd, 1 H, $J_{2c,3c}$ 8.0, $J_{3c,4c}$ 3.3 Hz, H-3c), and 7.34–8.15 (m, 15 H, 3 Ph).

Anal. Calc. for $C_{88}H_{112}N_2O_{44}Si$ (1929.9): C, 54.76; H, 5.84; N, 1.45. Found: C, 54.79; H, 5.81; N, 1.48.

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→6)-*O*-(2-acetamido-3,4-di-*O*-acetyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-β-*D*-glucopyranose* (**12C**). — A solution of **12B** (304 mg, 0.15 mmol) in dichloromethane (3 mL) was treated with trifluoroacetic acid, as described for **10C**, to yield amorphous **12C** (248 mg, 86%), $[\alpha]_D$ +22° (*c* 0.81, CH_2Cl_2); ν_{max} 3400 (NH, OH), 1740 and 1230 (ester), 1670 and 1540 (amide), and 720 cm^{-1} (Ph).

Anal. Calc. for $C_{83}H_{100}N_2O_{44}$ (1829.7): C, 54.48; H, 5.50; N, 1.53. Found: C, 54.51; H, 5.32; H, 1.55.

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→6)-*O*-(2-acetamido-3,4-di-*O*-acetyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-α-*D*-glucopyranosyltrichloroacetimidate* (**12D**). — A solution of **12C** (235 mg, 0.13 mmol) in dichloromethane was treated with trichloroacetonitrile (0.3 mL) in a fashion similar to that described for **10D**, to get amorphous **12D** (208 mg, 82%), $[\alpha]_D$ +27.9° (*c* 0.78, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 1.53, 1.77 (2 s, 6 H, 2 $NCOCH_3$), 1.60 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e}$ = 12.8 Hz, H-3e-*ax*), 1.90–2.14 (12 s, 36 H, 12 $OCOCH_3$), 2.40 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.22 (m, 1 H, H-2c), 3.81 (s, 3 H, CH_3O), 5.20 (dd, 1 H, $J_{6e,7e}$ 2.9, $J_{7e,8e}$ 9.6 Hz, H-7e), 5.51 (m, 1 H, H-8e), 5.74 (dd, 1 H, $J_{2c,3c}$ 8.0, $J_{3c,4c}$ 3.3 Hz, H-3c), 6.49 (d, 1 H, $J_{1a,2a}$ 3.66 Hz, H-1a), 7.34–8.2 (m, 15 H, 3 Ph), and 8.66 (s, 1 H, C=N*H*).

Anal. Calc. for $C_{85}H_{100}Cl_3N_3O_{44}$ (1974.1): C, 51.71; H, 5.10; N, 2.12. Found: C, 51.66; H, 5.14; N, 2.10.

*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→6)-*O*-(2,4-di-*O*-benzoyl-3-*O*-benzyl-β-*D*-galactopyranosyl)-(1→6)-*O*-(2-acetamido-3-*O*-benzyl-2-deoxy-β-*D*-ga-*

lactopyranosyl)-(1→4)-O-(2,3,6-tri-O-benzyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-benzyl-β-D-glucopyranoside (**13A**). — Glycosylation of **6** (183 mg, 0.14 mmol) with **8** (125 mg, 0.12 mmol), as described for **10A**, gave amorphous **13A** (224 mg, 70%), $[\alpha]_D$ +41.6° (*c* 0.7, CH_2Cl_2); ν_{max} 3400–3300 (NH, OH), 1740 and 1230 (ester), 1680 and 1540 (amide), 860 and 840 (Me_3Si), and 740 and 720 cm^{-1} (Ph); ^{1}H-n.m.r. ($CDCl_3$): δ 1.01 (m, 2 H, $Me_3SiCH_2CH_2O$) 1.61, 1.85 (2 s, 6 H, 2 $NCOCH_3$), 1.98, 2.00, 2.05, 2.11 (4 s, 12 H, 4 $OCOCH_3$), 2.49 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.8 Hz, H-3e-*eq*), 3.33 (s, 3 H, CH_3O), 4.71 (d, 1 H, $J_{1d,2d}$ 7.4 Hz, H-1d), 5.44 (dd, 1 H, $J_{2d,3d}$ 8.6 Hz, H-2d), 5.87 (br. d, 1 H, H-4d), and 7.14–8.21 (m, 50 H, 10 Ph).

Anal. Calc. for $C_{121}H_{140}N_2O_{35}Si$ (2210.5): C, 65.75; H, 6.39; N, 1.27. Found: C, 65.33; H, 6.34; N, 1.28.

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→6)-O-(3-O-acetyl-2,4-di-O-benzoyl-β-D-galactopyranosyl)-(1→6)-O-(2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-β-D-glucopyranoside* (**13B**). — A suspension of **13A** (431 mg, 0.19 mmol), in 8:1 ethanol–acetic acid (75 mL) was hydrogenolyzed, treated with aqueous acetic acid, and acetylated, as described for **12B**, to get amorphous **13B** (186 mg, 51%), $[\alpha]_D$ +0.6° (*c* 0.66, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 0.9 (m, 2 H, $Me_3SiCH_2CH_2O$), 1.84, 1.86 (2 s, 6 H, 2 $NCOCH_3$), 1.93–2.17 (13 s, 39 H, 13 $OCOCH_3$), 2.44 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.6 Hz, H-3e-*eq*), 3.12 (m, 1 H, H-2c), 3.35 (s, 3 H, CH_3O), 4.84 (d, 1 H, $J_{1d,2d}$ 8.0 Hz, H-1d), 5.77 (br. d, 1 H, H-4d), 5.79 (dd, 1 H, $J_{2c,3c}$ 8.0, $J_{3c,4c}$ 3.3 Hz, H-3c), and 7.34–8.15 (m, 10 H, 2 Ph).

Anal. Calc. for $C_{83}H_{110}N_2O_{44}Si$ (1867.9): C, 65.37; H, 5.94; N, 1.50. Found: C, 65.48; H, 5.98; N, 1.52.

O-(Methyl 5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→6)-O-(3-O-acetyl-2,4-di-O-benzoyl-β-D-galactopyranosyl)-(1→6)-O-(2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-β-D-glucopyranose* (**13C**). — A solution of **13B** (184 mg, 0.09 mmol) in dichloromethane (2 mL) was treated with trifluoroacetic acid, as described for **10C**, to get amorphous **13C** (157 mg, 90%), $[\alpha]_D$ +16° (*c* 0.81, CH_2Cl_2); ν_{max} 3400 (NH, OH), 1740 and 1230 (ester), 1670 and 1540 (amide), and 720 cm^{-1} (Ph).

Anal. Calc. for $C_{78}H_{98}N_2O_{44}$ (1767.6): C, 53.00; H, 5.59; N, 1.58. Found: C, 53.27; H, 5.55; N, 1.60.

O-(Methyl 5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→6)-O-(3-O-acetyl-2,4-di-O-benzoyl-β-D-galactopyranosyl)-(1→6)-O-(2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-acetyl-β-D-galactopyranosyl)-(1→4)-2,3,6-tri-O-acetyl-α-D-glucopyranosyl trichloroacetimidate* (**13D**). — A solution of **13C** (156 mg, 0.088 mmol) in dichloromethane was treated with trichloroacetonitrile (0.2 mL), in a fashion similar to that described for **10D**, to get amorphous **13D** (149 mg, 89%), $[\alpha]_D$ +0.6° (*c* 0.94, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): δ 1.84, 1.85 (2 s, 6 H, 2 $NCOCH_3$), 1.90–2.18 (13 s, 39 H, 13 $OCOCH_3$), 2.45 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.35 (s, 3 H, CH_3O), 5.70 (br. d, 1 H, H-4d), 5.78 (dd, 1 H, $J_{2c,3c}$ 8.0, $J_{3c,4c}$ 3.3 Hz, H-3c), 6.49 (d, 1 H, $J_{1a,2a}$ 3.66 Hz, H-1a), 7.34–8.2 (m, 15 H, 3 Ph), and 8.68 (s, 1 H, C=N*H*).

Anal. Calc. for $C_{80}H_{98}Cl_3N_3O_{44}$ (1912.0): C, 50.25; H, 5.17; N, 2.20. Found: C, 50.32; H, 5.23; N, 2.24.

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*-(2,3,6-tri-*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* (**10E**). — A mixture of **10D** (149 mg, 0.075 mmol), (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol (**9**, 58 mg, 0.14 mmol) and molecular sieves 4A (AW-300, 1.4 g) in dichloromethane (2 mL) was stirred for 12 h at room temperature, then cooled to 0°. Boron trifluoride etherate (0.04 mL) was added, the mixture was stirred at 0° for 12 h, and then filtered. The insolubles were washed with dichloromethane, and the combined filtrate and washings was washed with M sodium carbonate and water, dried (Na_2SO_4), and concentrated. Column chromatography (100:2 dichloromethane–methanol) of the residue on silica gel (40 g) gave amorphous **10E** (105 mg, 62%); $[\alpha]_D$ +6.0° (*c* 0.44, CH_2Cl_2); ν_{max} 3400 (NH), 2100 (N_3), 1740 and 1230 (ester), 1680 and 1540 (amide), and 720 cm^{-1} (Ph); ^{1}H-n.m.r. ($CDCl_3$): (aglycon) δ 0.88 (s, 3 H, CH_3), 1.24 (s, 22 H, 11 CH_2), 5.87 (m, 1 H, $J_{4,5}$ 13.9, $J_{5,6} = J_{5,6'} = 8.2$ Hz, H-5); (pentasaccharide) δ 1.60, 1.77 (2 s, 6 H, 2 $NCOCH_3$), 1.90–2.11 (12 s, 36 H, 12 $OCOCH_3$), 2.41 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.4 Hz, H-3e-*eq*), 3.01 (m, 1 H, H-2c), 3.81 (s, 3 H, CH_3O), 5.10 (d, 1 H, $J_{NH,5e}$ 9.0 Hz, N*H*-e), 5.19 (dd, 1 H, $J_{6c,7e}$ 2.6, $J_{7e,8e}$ 7.0 Hz, H-7e), 5.34 (d, 1 H, H-4d), 5.44 (dd, 1 H, H-2d), and 7.14–8.21 (m, 20 H, 4 Ph).

Anal. Calc. for $C_{108}H_{137}N_5O_{47}$ (2241.3): C, 57.87; H, 6.16; N, 3.12. Found: C, 57.79; H, 6.20; N, 3.15.

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*-(2,3,6-tri-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-β-*D*-glucopyranosyl)-(1→1)-*(2S,*3*R,*4*E)-*3-*O*-benzoyl-2-octadecanamido-4-octadecene-1,3-diol* (**10G**). — Through a stirred solution of **10E** (105 mg, 0.046 mmol) in aqueous 83% pyridine (15 mL) hydrogen sulfide was bubbled for 48 h at 0–15°, then the mixture was concentrated. A solution of the residue (**10F**) in dichloromethane was treated with octadecanoic acid (32 mg, 0.11 mmol) and 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (WSC, 24 mg, 0.12 mmol) for 24 h at room temperature. The mixture was diluted with dichloromethane (50 mL) and washed with water, dried (Na_2SO_4), and concentrated. Column chromatography (100:2 dichloromethane–methanol) of the residue on silica gel (30 g) gave amorphous **10G** (84 mg, 73%), $[\alpha]_D$ +3.4° (*c* 0.42, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): (aglycon) δ 0.88 (s, 6 H, 2 CH_3), 1.25 (s, 50 H, 25 CH_2), 5.85 (m, 1 H, $J_{4,5}$ 14.8, $J_{5,6} = J_{5,6'} = 6.8$ Hz, H-5); (pentasaccharide) δ 1.56, 1.78 (2 s, 6 H, 2 $NCOCH_3$), 1.91–2.14 (12 s, 36 H, 12 $OCOCH_3$), 2.46 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.01 (m, 1 H, H-2c), 3.81 (s, 3 H, CH_3O), 5.20 (dd, $J_{6e,7e}$ 2.6, $J_{7e,8e}$ 7.0 Hz, H-7e), 5.36 (br. d, 1 H, H-4d), 5.46 (dd, 1 H, H-2d), and 7.14–8.21 (m, 20 H, 4 Ph).

Anal. Calc. for $C_{126}H_{173}N_3O_{47}$ (2481.8): C, 60.98; H, 7.02; N, 1.69. Found: C, 60.62; H, 6.98; N, 1.71.

Ganglioside GM1b (**10H**). — A solution of **10G** (63 mg, 0.025 mmol) in methanol (5 mL) was stirred with sodium methoxide (20 mg) for 40 h at 45°. Water (0.5 mL) was added and the mixture was stirred for a further 16 h at room temperature, neutralized with Amberlite IR-120 (H^+) resin, and filtered. The resin was washed with 5:4:1 chloroform–methanol–water, and the combined filtrate and washings was concentrated. Column chromatography (5:4:1 chloroform–methanol–water) of the residue on Sephadex LH-20 gel (30 g) gave amorphous **10H** (35 mg, 90%); $[\alpha]_D$ +5.7° (*c* 0.35, 5:4:1 $CHCl_3$–MeOH–H_2O); ν_{max} 3500–3300 (NH, OH), 2950–2840 (methyl, methylene), 1720 (COOH), and 1680 and 1540 cm^{-1} (amide); ^1H-n.m.r. [$(CD_3)_2SO$–D_2O]: (aglycon) δ 0.85 (s, 6 H, 2 CH_3), 1.24 (s, 50 H, 25 CH_2), 1.46 (br. m, 2 H, $COCH_2CH_2$), 1.95 (q, 2 H, $CH{=}CHCH_2$), 2.03 (t, 2 H, $COCH_2$), 5.37 (dd, 1 H, $J_{3,4}$ 7.0, $J_{4,5}$ 15.4 Hz, H-4), 5.55 (m, 1 H, $J_{5,6(6')}$ 7.2 Hz, H-5); (pentasaccharide) δ 1.37 (t, 1 H, J_{gem} = $J_{3e\text{-}ax,4e}$ = 12 Hz, H-3e-*ax*), 1.80, 1.87 (2 s, 6 H, 2 $NCOCH_3$), 2.76 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.8 Hz, H-3e-*eq*), 3.01 (t, 1 H, H-2a), 3.78 (br. d, 1 H, H-4b), 4.22 (d, 1 H, $J_{1a,2a}$ 7.9 Hz, H-1a), 4.26 (d, 1 H, $J_{1b,2b}$ 7.7 Hz, H-1b), 4.28 (d, 1 H, $J_{1d,2d}$ 7.3 Hz, H-1d), 4.49 (d, 1 H, $J_{1c,2c}$ 8.0 Hz, H-1c).

Anal. Calc. for $C_{73}H_{131}N_3O_{31}$ (1546.9): C, 56.68; H, 8.53; N, 2.71. Found: C, 56.65; H, 8.55; N, 2.68.

O-*(Methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→6)-*O-*(3-*O*-acetyl-2,4-di-*O*-benzoyl-β-*D-*galactopyranosyl)-(1→3)-*O-*(2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-*D-*galactopyranosyl-(1→4)-*O-*(2,3,6-tri-*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* (**11E**). — A mixture of **11D** 178 mg, 0.093 mmol), (2*S*,3*R*,4*E*)-2-azido-3-*O*-benzoyl-4-octadecene-1,3-diol (**9**, 74 mg, 0.18 mmol), and molecular sieves 4A (AW-300, 1.6 g) in dichloromethane was stirred for 6 h at room temperature, then cooled to 0°. Trimethylsilyl trifluoromethanesulfonate (0.05mL) was added, the mixture was stirred at 0° for 16 h, and then filtered. The insoluble were washed with dichloromethane, and the combined filtrate and washings was washed with M sodium carbonate and water, dried (Na_2SO_4), and concentrated. Column chromatography (100:2 dichloromethane–methanol) of the residue on silica gel (40 g) gave amorphous **11E** (126 mg, 62%), $[\alpha]_D$ +3.9° (*c* 0.51 CH_2Cl_2); ν_{max} 3400 (NH), 2100 (N_3), 1740 and 1230 (ester), 1680 and 1540 (amide), and 720 cm^{-1} (Ph); ^1H-n.m.r. ($CDCl_3$): (aglycon) δ 0.88 (s, 3 H, CH_3), 1.24 (s, 22 H, 11 CH_2), 5.87 (m, 1 H, $J_{4,5}$ 14.1, $J_{5,6}$ = $J_{5,6'}$ = 8.2 Hz, H-5); (pentasaccharide) δ 1.85, 1.87 (2 s, 6 H, 2 $NCOCH_3$), 1.97–2.21 (13 s, 39 H, 13 $OCOCH_3$), 2.44 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.4 Hz, H-3e-*eq*), 3.11 (m, 1 H, H-2c), 3.43 (s, 3 H, CH_3O), 5.16 (dd, 1 H, $J_{6e,7e}$ 2.6, $J_{7e,8e}$ 7.0 Hz, H-7e), 5.44 (dd, 1 H, H-2d), 5.74 (d, 1 H, H-4d), and 7.4–8.15 (m, 15 H, 3 Ph).

Anal. Calc. for $C_{103}H_{135}N_5O_{46}$ (2179.2): C, 56.77; H, 6.24; N, 3.21. Found: C, 56.89; H, 6.20; N, 3.17.

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

O-*(2,3,6-tri-*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* (**11G**). — Selective reduction of the azide group in **11E** (120 mg, 0.055 mmol) and subsequent coupling with octadecanoic acid (37 mg, 0.13 mmol), as described for **10G**, gave amorphous **11G** (109 mg, 82%), $[\alpha]_D$ +8.4° (*c* 0.31, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): (aglycon) δ 0.88 (s, 6 H, 2 CH_3), 1.25 (s, 50 H, 25 CH_2), 5.85 (m, 1 H, $J_{4,5}$ 13.8, $J_{5,6} = J_{5,6'} = 6.8$ Hz, H-5); (pentasaccharide) δ 1.85, 1.86 (2 s, 6 H, 2 $NCOCH_3$), 1.93–2.18 (13 s, 39 H, 13 $OCOCH_3$), 2.44 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.12 (m, 1 H, H-2c), 3.35 (s, 3 H, CH_3O), 5.10 (dd, 1 H, $J_{6e,7e}$ 2.3, $J_{7e,8e}$ 7.1 Hz, H-7e), 5.44 (m, 1 H, H-8e), 5.78 (d, 1 H, $J_{3d,4d}$ 3.3 Hz, H-4d), and 7.14–8.21 (m, 15 H, 3 Ph).

Anal. Calc. for $C_{121}H_{171}N_3O_{49}$ (2419.7): C, 60.06; H, 7.12; N, 1.74. Found: C, 59.98; H, 7.00; N, 1.75.

Ganglioside GM1b analog **11H**. — A methanolic solution of **11G** (79 mg, 0.032 mmol) was treated with sodium methoxide followed by water and worked up, as described for **10H**, to get amorphous **11H** (43 mg, 86%), $[\alpha]_D$ −4.2° (*c* 0.72, 5:4:1 $CHCl_3$–MeOH–H_2O); ν_{max} 3500–3300 (NH, OH), 2950–2840 (methyl, methylene), 1720 (COOH), and 1680 and 1540 cm^{-1} (amide); ^{1}H-n.m.r. [$(CD_3)_2SO$–D_2O]: (aglycon) δ 0.85 (s, 6 H, 2 CH_3), 1.24 (s, 50 H, 25 CH_2), 1.46 (br. m, 2 H, $COCH_2CH_2$), 1.95 (q, 2 H, $CH=CHCH_2$), 2.03 (t, 2 H, $COCH_2$), 5.37 (dd, 1 H, $J_{3,4}$ 7.0, $J_{4,5}$ 14.8 Hz, H-4), 5.55 (m, 1 H, $J_{5,6(6')}$ 7.0 Hz, H-5); (pentasaccharide) δ 1.37 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e} = 12$ Hz, H-3e-*ax*), 1.80, 1.87 (2 s, 6 H, 2 $NCOCH_3$), 2.76 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.8 Hz, H-3e-*eq*), 3.05 (t, 1 H, H-2a), 3.82 (br. d, 1 H, H-4b), 4.22 (d, 1 H, $J_{1a,2a}$ 7.7 Hz, H-1a), 4.26 (d, 1 H, $J_{1b,2b}$ 7.3 Hz, H-1b), 4.28 (d, 1 H, $J_{1d,2d}$ 7.7 Hz, H-1d), 4.49 (d, 1 H, $J_{1c,2c}$ 8.0 Hz, H-1c).

Anal. Calc. for $C_{73}H_{131}N_3O_{31}$ (1546.9): C, 56.68; H, 8.53; N, 2.71. Found: C, 56.56; H, 8.48; N, 2.73.

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→6)-*O*-(2-acetamido-3,4-di-*O*-acetyl-2-deoxy-β-*D*-galactopyranosyl)-(1→4)-*O*-(2,3,6-tri-*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* (**12E**). — The coupling of **12D** (98 mg, 0.049 mmol) and **9** (35 mg, 0.084 mmol), as described for **10E**, yielded amorphous **12E** (56 mg, 50.5%), $[\alpha]_D$ +2.0° (*c* 0.50, CH_2Cl_2); ν_{max} 3400 (NH), 2100 (N_3), 1740 and 1230 (ester), 1680 and 1540 (amide), and 720 cm^{-1} (Ph); ^{1}H-n.m.r. ($CDCl_3$): (aglycon) δ 0.87 (s, 3 H, CH_3), 1.23 (s, 22 H, 11 CH_2), 5.89 (m, 1 H, $J_{4,5}$ 11.9, $J_{5,6} = J_{5,6'} = 7.3$ Hz, H-5); (pentasaccharide) δ 1.53, 1.77 (2 s, 6 H, 2 $NCOCH_3$), 1.91–2.15 (12 s, 36 H, 12 $OCOCH_3$), 2.43 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.4 Hz, H-3e-*eq*), 3.01 (m, 1 H, H-2c), 3.82 (s, 3 H, CH_3O), 5.10 (d, 1 H, $J_{NH,5e}$ 9.0 Hz, N*H*), 5.19 (dd, 1 H, $J_{6e,7e}$ 2.6, $J_{7e,8e}$ 7.0 Hz, H-7e), 5.34 (d, 1 H, H-4d), 5.44 (dd, 1 H, H-2d), 5.52 (m, 1 H, H-8e), 5.74 (dd, 1 H, $J_{2c,3c}$ 8.0, $J_{3c,4c}$ 3.3 Hz, H-3c), and 7.14–8.21 (m, 20 H, 4 Ph).

Anal. Calc. for $C_{108}H_{137}N_5O_{47}$ (2241.3): C, 57.87; H, 6.16; N, 3.12. Found: C, 57.79; H, 6.20; N, 3.15.

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→6)-O-(2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-acetyl-β-D-galactopyranosyl)-(1→4)-O-(2,3,6-tri-O-acetyl-β-D-glucopyranosyl)-(1→1)-(2S,2R,4E)-3-O-benzoyl-2-octadecanamido-4-octadecene-1,3-diol (**12G**). — Selective reduction of the azide group in **12E** (56 mg, 0.025 mmol) and subsequent coupling with octadecanoic acid (21 mg, 0.073 mmol), as described for **10G**, gave amorphous **12G** (46 mg, 74%), $[\alpha]_D$ +8.4° (*c* 0.97, CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): (aglycon) δ 0.87 (s, 6 H, 2 CH_3), 1.25 (s, 50 H, 25 CH_2), 5.85 (m, 1 H, $J_{4,5}$ 13.8, $J_{5,6} = J_{5,6'}$ = 6.8 Hz, H-5); (pentasaccharide) δ 1.53, 1.77 (2 s, 6 H, 2 $NCOCH_3$), 1.91–2.14 (12 s, 36 H, 12 $OCOCH_3$), 2.44 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.02 (m, 1 H, H-2c), 3.82 (s, 3 H, CH_3O), 5.16 (dd, 1 H, $J_{6e,7e}$ 2.3, $J_{7e,8e}$ 7.1 Hz, H-7e), 5.44 (m, 1 H, H-8e), 5.34 (d, 1 H, H-4d), 5.74 (dd, 1 H, $J_{2c,3c}$ 8.0, $J_{3c,4c}$ 2.9 Hz, H-3c), and 7.14–8.21 (m, 20 H, 4 Ph).

Anal. Calc. for $C_{126}H_{173}N_3O_{47}$ (2481.8): C, 60.98; H, 7.02; N, 1.69. Found: C, 70.18; H, 6.98; N, 1.73.

Ganglioside GM1b analog **12H**. — *O*-Deacylation and saponification of **12G** (35 mg, 0.014 mmol), as described for **10H**, yielded amorphous **12H** (19 mg, 86%), $[\alpha]_D$ +12.0° (*c* 0.50, 5:4:1 $CHCl_2$–MeOH–H_2O); ν_{max} 3500–3300 (NH, OH), 2950–2840 (methyl, methylene), 1720 (COOH), and 1680 and 1540 cm^{-1} (amide); ^{1}H-n.m.r. [$(CD_3)_2SO$–D_2O]: δ (aglycon) 0.85 (s, 6 H, 2 CH_3), 1.24 (s, 50 H, 25 CH_2), 1.46 (br. m, 2 H, $COCH_2CH_2$), 1.95 (q, 2 H, $CH{=}CHCH_2$), 2.03 (t, 2 H, $COCH_2$), 5.31 (dd, 1 H, $J_{3,4}$ 8.3, $J_{4,5}$ 15.4 Hz, H-4), 5.49 (m, 1 H, $J_{5,6(6')}$ 7.0 Hz, H-5); (pentasaccharide) δ 1.37 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e}$ = 12 Hz, H-3e-*ax*), 1.80, 1.87 (2 s, 6 H, 2 $NCOCH_3$), 2.76 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.8 Hz, H-3e-*eq*), 3.01 (t, 1 H, H-2a), 3.78 (d, 1 H, H-4b), 4.21 (d, 1 H, $J_{1a,2a}$ 7.9 Hz, H-1a), 4.24 (d, 1 H, $J_{1b,2b}$ 8.6 Hz, H-1b), 4.26 (d, 1 H, $J_{1d,2d}$ ~8.0 Hz, H-1d), and 4.49 (d, 1 H, $J_{1c,2c}$ 8.3 Hz, H-1c).

Anal. Calc. for $C_{73}H_{131}N_3O_{31}$ (1546.9): C, 56.68; H, 8.53; N, 2.71. Found: C, 56.60; H, 8.52; N, 2.67.

*O-(Methyl 5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto*-2-nonulopyranosylonate)-(2→6)-O-(3-O-acetyl-2,4-di-O-benzoyl-β-D-galactopyranosyl)-(1→6)-O-(2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-O-(2,3,6-tri-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* (**13E**). — Coupling of **13D** (172 mg, 0.09 mmol) and **9** (86 mg, 0.2 mmol), as described for **11E**, gave amorphous **13E** (140 mg, 71%), $[\alpha]_D$ −11.3° (*c* 1.18, $CHCl_3$); ν_{max} 3400 (NH), 2100 (N_3), 1740 and 1230 (ester), 1680 and 1540 (amide), and 720 cm^{-1} (Ph); ^{1}H-n.m.r. ($CDCl_3$): (aglycon) δ 0.88 (s, 3 H, CH_3), 1.24 (s, 22 H, 11 CH_2), 5.87 (m, 1 H, $J_{4,5}$ 13.9, $J_{5,6} = J_{5,6'}$ = 8.2 Hz, H-5); (pentasaccharide) δ 1.84, 1.89 (2 s, 6 H, 2 $NCOCH_3$), 1.90–2.11 (13 s, 39 H, 13 $OCOCH_3$), 2.45 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.4 Hz, H-3e-*eq*), 3.16 (m, 1 H, H-2c), 3.36 (s, 3 H, CH_3O), 5.10 (dd, 1 H, $J_{6e,7e}$ 2.3, $J_{7e,8e}$ 7.1 Hz, H-7e), 5.44 (m, 1 H, H-8e), 5.78 (d, 1 H, $J_{3d,4d}$ 3.3 Hz, H-4d), 5.80 (dd, 1 H, $J_{2c,3c}$ 7.8, $J_{3c,4c}$ 3.3 Hz, H-3c), and 7.14–8.21 (m, 15 H, 3 Ph).

Anal. Calc. for $C_{103}H_{135}N_5O_{46}$ (2179.2): C, 56.77; H, 6.24; N, 3.21. Found: C, 56.92; H, 6.25; N, 3.26.

*O-(Methyl 5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-*D-glycero-α-D-galac-

to-2-nonulopyranosylonate)-(2→6)-O-(3-O-acetyl-2,4-di-O-benzoyl-β-D-galactopyranosyl)-(1→6)-O-(2-acetamido-3,4-di-O-acetyl-2-deoxy-β-D-galactopyranosyl)-(1→4)-O-(2,3,6-tri-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 (**13G**). — Selective reduction of the azide group in **13E** (120 mg, 0.055 mmol) and subsequent coupling with octadecanoic acid (35 mg, 0.12 mmol), as described for **10G**, gave amorphous **13G** (105 mg, 79%), $[\alpha]_D$ +6.6° (*c* 0.44 CH_2Cl_2); ^{1}H-n.m.r. ($CDCl_3$): (aglycon) δ 0.88 (s, 6 H, 2 CH_3), 1.25 (s, 50 H, 25 CH_2), 5.85 (m, 1 H, $J_{4,5}$ 13.8, $J_{5,6} = J_{5,6'} = 6.8$ Hz, H-5); (pentasaccharide) δ 1.85, 1.86 (2 s, 6 H, 2 $NCOCH_3$), 1.93–2.18 (13 s, 39 H, 13 $OCOCH_3$), 2.44 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 4.7 Hz, H-3e-*eq*), 3.12 (m, 1 H, H-2c), 3.35 (s, 3 H, CH_3O), 5.10 (dd, 1 H, $J_{6e,7e}$ 2.3, $J_{7e,8e}$ 7.1 Hz, H-7e), 5.44 (m, 1 H, H-8e), 5.78 (d, 1 H, $J_{3d,4d}$ 3.3 Hz, H-4d), 5.80 (dd, 1 H, $J_{2c,3c}$ 7.8, $J_{3c,4c}$ 3.3 Hz, H-3c), and 7.14–8.21 (m, 15 H, 3 Ph).

Anal. Calc. for $C_{121}H_{171}N_3O_{49}$ (2419.7): C, 60.06; H, 7.12; N, 1.74. Found: C, 60.15; H, 7.11; N, 1.78.

Ganglioside GM1b analog **13H**. — *O*-Deacylation and saponification of **13G** (83 mg, 0.034 mmol), as described for **10H**, yielded amorphous **13H** (49 mg, 92%), $[\alpha]_D$ +11.5 (*c* 0.5, 5:4:1 $CHCl_3$–MeOH–H_2O); ν_{max} 3500–3300 (NH, OH), 2950–2840 (methyl, methylene), 1720 (COOH), and 1680 and 1540 cm^{-1} (amide); ^{1}H-n.m.r. [$(CD_3)_2SO$–D_2O]: δ (aglycon) 0.85 (s, 6 H, 2 CH_3), 1.25 (s, 50 H, 25 CH_2), 1.46 (br. m, 2 H, $COCH_2CH_2$), 1.93 (q, 2 H, $CH=CHCH_2$), 2.05 (t, 2 H, $COCH_2$), 5.37 (dd, 1 H, $J_{3,4}$ 7.0, $J_{4,5}$ 14.8 Hz, H-4), 5.55 (m, 1 H, $J_{5,6(6')}$ 7.2 Hz, H-5); (pentasaccharide) δ 1.37 (t, 1 H, $J_{gem} = J_{3e\text{-}ax,4e} = 12$ Hz, H-3e-*ax*), 1.80, 1.85 (2 s, 6 H, 2 $NCOCH_3$), 2.76 (dd, 1 H, $J_{3e\text{-}eq,4e}$ 5.0 Hz, H-3e-*eq*), 3.01 (t, 1 H, H-2a), 3.80 (br. d, 1 H, H-4b), 4.22 (d, 1 H, $J_{1a,2a}$ 7.9 Hz, H-1a), 4.26 (d, 1 H, $J_{1b,2b}$ ~8.0 Hz, H-1b), 4.28 (d, 1 H, $J_{1d,2d}$ 7.3, H-1d), 4.50 (d, 1 H, $J_{1c,2c}$ 7.7, H-1c).

Anal. Calc. for $C_{73}H_{131}N_3O_{31}$ (1546.9): C, 56.68; H, 8.53; N, 2.71. Found: C, 56.58; H, 8.59; N, 2.66.

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