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Synthesis of sialyl Le^x ganglioside analogues modified at C-6 of the galactose residue to elucidate the mechanism of selection recognition[1]

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Abstract

Sialyl Lewis X ganglioside analogues modified at C-6 of the galactose residue, having 6-*O*-methoxy, 6-acetamido and 6-amino functional groups, have been synthesized. Treatment of 2-(trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-glycero-α-D-galacto-2-nonulopyranosylonate)-(2→3)-2-*O*-benzoyl-β-D-galactopyranoside with trimethyloxonium tetrafluoroborate or Tf_2O, followed by NaN_3, gave the 6-*O*-methyl and 6-azido derivatives, respectively, which were converted into their respective methyl 1-thioglycoside derivatives. The glycosyl donors obtained were coupled with 2-(trimethylsilyl)ethyl 2-acetamido-6-*O*-benzyl-2-deoxy-3-*O*-(4-methoxybenzyl)-β-D-glucopyranosyl-(1→3)-2,4,6-tri-*O*-benzyl-β-D-galactopyranosyl-(1→4)-2,3,6-tri-O-benzyl-β-D-galactopyranoside in the presence of dimethyl(methylthio)sulfonium triflate (DMTST) to give their respective pentasaccharides. The glycosylation of the pentasaccharide acceptors derived from their precursors by removal of the 4-methoxybenzyl group, with phenyl 1-thioglycoside derivative of L-fucose using *N*-iodosuccinimide–TfOH afforded the corresponding hexasaccharides, which were transformed in good yield, via reductive removal of the benzyl group, the simultaneous transformation of azide to amine and acetamide, O-deacylation and saponification of the methyl ester into the target compounds without the ceramide groups. On the other hand, the proper manipulation of the protecting group of the hexasaccharides, including a transformation of azide into acetamide and trifluoroacetamide, gave the hexasaccharide imidates, which were coupled with (2*S*,3*R*,4*E*)-2-azido-3-*O*-*tert*-butyldiphenylsilyl-4-octadecene-1,3-diol. Selective reduction of the azido group, *N*-acylation with octadecanoic acid, and the complete removal of the protecting groups gave the desired sialyl Le^X ganglioside analogues. © 1998 Elsevier Science Ltd. All rights reserved

Keywords: Sialyl Le^x; Selectin; Ganglioside

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1. Introduction

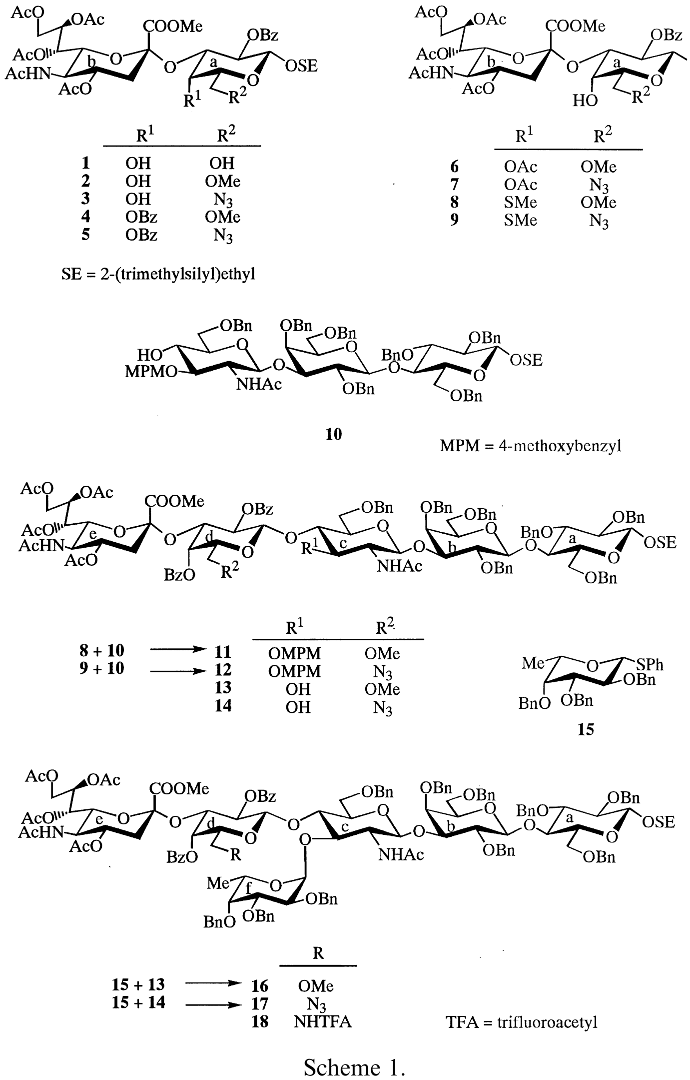
Selectins (E-, P-, and L-selection) are a family of calcium-dependent adhesion molecules [2–5] that are demonstrated to recognize sialyl Lewis X (sLe^x) as a ligand [6–8]. In our continuing efforts [9–11] to elucidate the mechanism of the selectin–sLe^X interaction, we have synthesized sLe^X ganglioside derivatives that are sulfated at C-6 of either the D-galactose and/or the *N*-acetyl-D-glucosamine residue [12] and have examined their potency as ligands for selectins [13]. It is of interest that the introduction of a sulfo group to the C-6 of D-galactose completely abolished the ligand activity to E-selectin, and that this could be explained by a repulsion between the sulfo group of sLe^X and the negatively charged residue, Gln 80 and Asp 100, of E-selectin [14].

In view of these facts, we describe herein the synthesis of the sLe^X ganglioside analogues with modification at C-6 of the D-galactose residue, such as the 6-*O*-methoxy, 6-acetamido and 6-amino derivatives, which are useful probes to prove the hypothesis described above.

2. Results and discussion

For the systematic synthesis of the galactose-modified sialyl Le^X hexasaccharides, we employed 2-(trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate)-(2$\rightarrow$3)-2-*O*-benzoyl-β-D-galactopyranoside [12] (**1**) as the common intermediate (Scheme 1).

Treatment [15] of **1** with 2,6-di-*tert*-butyl-4-methylpyridine and trimethyloxonium tetrafluoroborate in dichloromethane for 4 h at 0 °C afforded the 6-*O*-methyl derivative **2** in 86% yield,

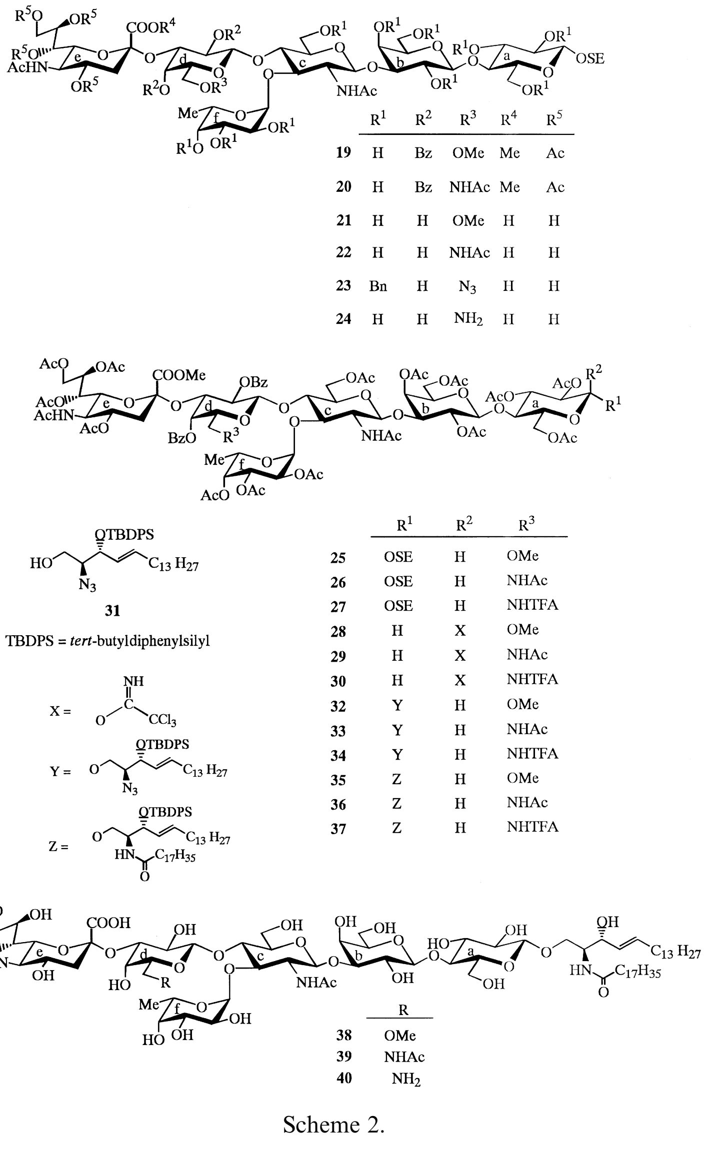


Scheme 1.

while 6-*O*-triflation of **1** and subsequent treatment with sodium azide gave the 6-azido derivative **3** in 60% yield. The compounds **2** and **3** were treated with benzoic anhydride in the presence of 4-dimethylaminopyridine to give 4-benzoates **4** (92%) and **5** (93%), which, on treatment [16] with boron trifluoride etherate in toluene–acetic anhydride, gave the β-1-acetates **6** (91%) and **7** (84%). Conversion of **6** and **7** into the corresponding methyl β-thioglycosides **8** (94%) and **9** (75%) was achieved by treatment [17] with methylthiotrimethylsilane and boron trifluoride etherate in dichloromethane.

Glycosylation of **10** [18] with 1.5 equiv of **8** in dichloromethane for 21 h at 0 °C in the presence of 8.0 equiv of dimethyl(methylthio)sulfonium triflate (DMTST) [19] and powdered 4A molecular sieves (4Å MS) gave the expected pentasaccharide derivative **11** (90%). In the same way coupling of **10** and **9** gave the corresponding pentasaccharide **12** (83%).

Removal [20] of the 4-methoxybenzyl group in **11** and **12** in dichloromethane in the presence of tin(II) chloride, anisole and chlorotrimethylsilane for 7 h at 20 °C afforded the desired glycosyl acceptors **13** (90%) and **14** (96%). The glycosylation of **13** and **14** with phenyl 2,3,4-tri-*O*-benzyl-1-thio-β-D-fucopyranoside [12] (**15**) in the presence of *N*-iodosuccinimide (NIS)–trifluoromethane- sulfonic acid (TfOH) [21,22] and 4A MS in benzene for 7 h at 7 °C gave the desired hexasaccharide **16** (96%) and **17** (89%), respectively. The azide of **17** was converted into the trifluoroacetamide **18** (46%) by successive treatments with triphenylphosphine in benzene–water and trifluoroacetic anhydride in dichloromethane–pyridine, to serve an intermediate of the 6-amino derivative **40** (Scheme 2).



	R¹	R²	R³	R⁴	R⁵
19	H	Bz	OMe	Me	Ac
20	H	Bz	NHAc	Me	Ac
21	H	H	OMe	H	H
22	H	H	NHAc	H	H
23	Bn	H	N_3	H	H
24	H	H	NH_2	H	H

TBDPS = *tert*-butyldiphenylsilyl

	R¹	R²	R³
25	OSE	H	OMe
26	OSE	H	NHAc
27	OSE	H	NHTFA
28	H	X	OMe
29	H	X	NHAc
30	H	X	NHTFA
32	Y	H	OMe
33	Y	H	NHAc
34	Y	H	NHTFA
35	Z	H	OMe
36	Z	H	NHAc
37	Z	H	NHTFA

	R
38	OMe
39	NHAc
40	NH_2

Scheme 2.

Hydrogenolytic removal of the benzyl groups in **16** over 10% Pd–C in acetic acid gave **19** (53%), and a similar hydrogenation of **17** in the presence of acetic anhydride gave the 6-acetamido derivative **20** (57%), both of which were converted by O-deacylation with sodium methoxide in methanol and subsequent saponification of the methyl ester, into the target compounds **21** (99%) and **22** (98%), while O-deacylation and saponification of **17** (91% in two steps), followed by hydrogenation (77%) over $Pd(OH)_2$, gave the 6-amino derivative **24**.

Removal of the benzyl groups from **16**, **17**, and **18** by catalytic hydrogenolysis over $Pd(OH)_2$ and subsequent acetylation gave the per-*O*-acylated hexasaccharides **25** (78%), **26** (77%), and **27** (80%). The azido group in **17** was simultaneously transformed into the acetamido, groups as described for **20**. For the selective removal of the 2–(trimethylsilyl)ethyl group, the fully acylated oligosaccharides **25**, **26** and **27** were treated [23] with trifluoroacetic acid in dichloromethane for 3 h at room temperature to give the 1-hydroxy compounds, which, on further treatment [24] with trichloroacetonitrile in the presence of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) in dichloromethane for 2 h at 0 °C, gave the corresponding trichloroacetimidates **28** (81%), **29** (88%), and **30** (84%), respectively.

Glycosylation of (2*S*,3*R*,4*E*)-2-azido-3-*O*-(*tert*-butyldiphenylsilyl)-4-octadecene-1,3-diol [25] (**31**) with the glycosyl donors **28**–**30** which was carried out in the presence of trimethylsilyl trifluoromethanesulfonate and 4A MS (AW-300) for 24 h at 0 °C, afforded the desired *β*-glycosides **32** (33%), **33** (58%) and **34** (65%), respectively.

Selective reduction [26] of the azido group in **32**–**34** with triphenylphosphine in 20:1 benzene–water gave the amine, which, on condensation with stearic acid using 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride in dichloromethane, gave the fully protected sialyl Le^X ganglioside derivatives **35** (81%), **36** (70%), and **37** (48%), respectively.

Finally, removal [25] of the *tert*-butyldiphenylsilyl group in **35**–**37** with 1.0 M tetrabutylammonium fluoride in acetonitrile, O-deacylation, and simultaneous deprotection of *N*-trifluoroacetyl group with sodium methoxide in 5:1 methanol–tetrahydrofuran for 24 h at 40 °C, and subsequent saponification of the methyl ester afforded the desired sialyl Le^X ganglioside analogues **38** (98%), **39** (87%) and **40** (93%) that are modified at C-6 of the galactose residue. All of the products **38**–**40** unexpectedly lost their binding activity to E-selectin.[2] We have already reported that the binding activity of sLe^X ganglioside to E-selectin was completely abolished, not only by a sulfation [13], but also by a deoxygenation [11,27] of C-6 of the galactose residue. Taking account of these results, it is strongly suggested that E-selectin recognizes the C-6 of the galactose residue of sLe^X in a very severe manner.

3. Experimental

General procedures.—Specific rotations were determined with a Union PM-201 polarimeter at 25 °C, and ^1H NMR spectra were recorded at 400 MHz with a Varian Inova 400, or 200 MHz with a Varian Gemini-2000 spectrometer. Preparative TLC was performed on Silica Gel 60 (E. Merck), and column chromatography on silica gel (Fuji Silysia Co., 300 mesh) was accomplished with the solvent systems (v/v) specified. Concentrations and evaporations were conducted in vacuo.

*2-(Trimethylsilyl)ethyl (methyl 2-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-*O*-benzoyl-6-*O*-methyl-β-*D*–galactopyranoside* (**2**).—To a solution of **1** (400 mg, 0.47 mmol) in CH_2Cl_2 (2 mL), cooled to 0 °C, was added 2,6-di-*tert*-butyl-4-methylpyridine (288 mg, 1.4 mmol) and trimethyloxonium tetrafluoroborate (173 mg, 1.2 mmol), and the mixture was stirred for 4 h at 0 °C. After completion of the reaction, MeOH (2 mL) was added to the mixture, which was then concentrated. Column chromatography (35:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **2** (352 mg, 86%) as an amorphous mass: $[\alpha]_D + 2.9°$ (*c* 0.9, $CHCl_3$); IR (film) 3550, 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.57–8.27 (m, 5 H, Ph), 5.62 (m, 1 H, H-8), 5.42 (dd, 1 H, H-2a), 4.84 (m, 1 H, H-4b), 4.52 (dd, 1 H, $J_{2,3}$ 9.9 Hz, $J_{3,4}$ 2.9 Hz, H-3a), 4.43 (dd, 1 H, J_{gem} 12.5, $J_{8,9'}$ 2.4 Hz, H-9′), 3.91 (s, 3 H, COO*Me*), 3.53 (s, 3 H, MeO), 2.69 (dd, 1 H, J_{gem} 12.8, $J_{3eq},4$, 4.6 Hz, H-3b*eq*), 2.19, 2.09, 1.93, 1.69, (4 s, 12 H, 4 AcO) 1.38 (s, 3 H, AcN), 0.94 (m, 2H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{39}H_{57}NO_{19}Si$ (871.96): C, 53.72; H, 6.59; N, 1.61. Found: C, 53.45; H, 6.42; N, 1.44.

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[2] The detailed results of the biological studies will be published by H. Kondo et al. elsewhere.

2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-6-azido-2*-O-*benzoyl-6-deoxy*-β-D-*galactopyranoside* (**3**).—To a solution of **1** (100 mg, 0.12 mmol) in pyridine (3 mL) and CH_2Cl_2 (3 mL), cooled to −20 °C, was added trifluoromethanesulfonic anhydride (39 μL, 0.23 mmol), and the mixture was stirred for 1 h at −20 °C then extracted with CH_2Cl_2. The extract was washed with 2 M HCl, M Na_2CO_3 and water, dried (Na_2SO_4) and concentrated. The residue was dissolved in DMF (5 mL) and treated with sodium azide (76.0 mg, 1.2 mmol) for 12 h at −10 °C, then extracted with EtOAc. The extract was washed with water, dried (Na_2SO_4) and concentrated. Column chromatography (70:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **3** (64.1 mg, 60%) as an amorphous mass: $[\alpha]_D + 7.7°$ (*c* 0.7, $CHCl_3$); IR (film) 3550, 3350, 2950, 2130,1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.50–8.27 (m, 5 H, Ph), 5.64 (m, 1 H, H-8), 4.89 (m, 1 H, H-4b), 4.56 (dd, 1 H, $J_{2,3} = 9.8$ Hz, $J3,4$ 2.9 Hz, H-3a), 4.41 (dd, 1 H, J_{gem} 12.5, $J_{8,9'}$ 1.6 Hz, H-9′), 3.90 (s, 3 H, COOMe), 2.62 (dd, 1 H, J_{gem} 12.7, J_{3eq4}, 4.6 Hz, H-3b*eq*), 2.26, 2.18, 2.08, 1.92, (4 s, 12 H, 4 AcO) 1.72 (s, 3 H, AcN), 0.98 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{38}H_{54}$ $N_4O_{18}Si$ (882.95): C, 51.69; H, 6.16; N, 6.35. Found: C, 51.57; H, 5.94; N, 6.27.

2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra–O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di*-O-*benzoyl-6*-O-*methyl*-β-D-*galactopyranoside* (**4**).—To a solution of **2** (352 mg, 0.44 mmol) in pyridine (3 mL) containing 4-dimethylaminopyridine (15.0 mg, 0.12 mmol) was added benzoic anhydride (183 mg, 0.81 mmol), and the mixture was stirred for 24 h at room temperature. At the end of this time the mixture was concentrated and extracted with CH_2Cl_2. The extract was successively washed with 2 M HCl and water, dried (Na_2SO_4) and concentrated. Column chromatography (60:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **4** (350 mg, 92%) as an amorphous mass: $[\alpha]_D$ +44.5° (*c* 1.4, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.45–8.27 (m, 10 H, 2 Ph), 5.64 (m, 1 H, H-8), 5.39 (dd, 1 H, $J_{1,2}$ 7.9, $J_{2,3}$ 10.1 Hz, H-2a), 5.24 (d, 1 H, $J_{3,4}$ 3.1 Hz, H-4a), 5.19 (dd, 1 H, $J_{6,7}$ 2.6, $J_{7,8}$ 9.3 Hz, H-7), 5.06 (d, 1 H, $J_{5,NH}$ 10.1 Hz, NH), 4.82 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1a), 4.76 (dd, 1 H, $J_{2,3}$ 10.1 Hz, $J_{3,4}$ 3.4 Hz, H-3a), 4.35 (dd, 1 H, J_{gem} 12.5, $J_{8,9'}$ 2.4 Hz, H-9′), 3.90 (s, 3 H, COO*Me*), 3.33 (s, 3 H, MeO), 2.62 (dd, 1 H, J_{gem} 12.9, $J_{3eq,4}$, 4.5 Hz, H-3b*eq*), 2.23, 2.08, 1.92, 1.78, (4 s, 12 H, 4 AcO) 1.44 (s, 3 H, AcN), 0.95 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{44}H_{59}NO_{20}Si$ (950.03): C, 55.63; H, 6.26; N, 1.47. Found: C, 55.57; H, 5.98; N, 1.40.

2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-6-azido-2,4-di*-O-*benzoyl-6-deoxy*-β-D-*galactopyranoside* (**5**).—To a solution of **3** (670 mg, 0.759 mmol) in pyridine (6 mL) containing 4-dimethylaminopyridine (28 mg, 0.23 mmol) was added benzoic anhydride (344 mg, 1.5 mmol), and the mixture was stirred for 20 h at room temperature. Workup as described for **4** gave **5** (679 mg, 93%) as an amorphous mass: $[\alpha]_D$ +44.5° (*c* 1.4, $CHCl_3$); IR (film) 3350, 2950, 2130, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.38–8.30 (m, 10 H, 2 Ph), 5.64 (m, 1 H, H-8), 5.55 (dd, 1 H, $J_{2,3}$ 10.1 Hz, H-2a), 4.82 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1a), 4.44 (dd, 1 H, J_{gem} 12.1, $J_{8,9'}$ 2.4 Hz, H-9′), 3.88 (s, 3 H, COO*Me*), 2.69 (dd, 1 H, J_{gem} 12.7, $J_{3eq,4}$ 4.4 Hz, H-3b*eq*), 2.32, 2.17, 1.99, 1.86 (4 s, 12 H, 4 AcO), 1.56 (s, 3 H AcN), 0.97 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{43}H_{56}N_4O_{19}Si$ (961.02): C, 53.74; H, 5.87; N, 5.83. Found: C, 53.59; H, 5.75; N, 5.55.

Methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate-(2→3)-1*-O-*acetyl-2,4-di*-O-*benzoyl-6*-O-*methyl*-β-D-*galacto-pyranose* (**6**).—To a solution of **4** (197 mg, 0.201 mmol) in toluene (2 mL) was added acetic anhydride (0.27 mL, 2.9 mmol) and boron trifluoride etherate ($BF_3{\cdot}OEt_2$, 48.7 μL, 0.18 mmol), and the mixture was stirred for 3 h at room temperature and then extracted with CH_2Cl_2. The extract was successively washed with M Na_2CO_3 and water, dried (Na_2SO_4), and concentrated. Column chromatography (EtOAc) of the residue on silica gel gave **6** (170 mg, 91%) as an amorphous mass: $[\alpha]_D$ +62.5° (*c* 0.8, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.38–8.13 (m, 10 H, 2 Ph), 6.12 (d, 1 H, H-1a), 5.59 (m, 1 H, H-8), 5.52 (dd, 1 H, $J_{1,2}$ 8.3 Hz, H-2a), 5.31 (d, 1 H, $J_{3,4}$ 2.9 Hz, H-4a), 5.19 (dd, 1 H, $J_{6,7}$ 2.8, $J_{7,8}$ 9.2 Hz, H-7), 5.04 (d, 1 H, $J_{5,NH}$ 9.9 Hz, NH), 4.70 (dd, 1 H, $J_{2,3}$ 9.8 Hz, $J_{3,4}$ 2.4 Hz, H-3a), 4.33 (dd, 1 H, J_{gem} 12.3, $J_{8,9'}$ 2.4 Hz, H-9′), 3.92 (s, 3 H, COO*Me*), 3.30 (s, 3 H, MeO), 4.6 Hz, H-3b*eq*), 2.48 (dd, 1 H, J_{gem} 12.6, $J_{3eq,4}$, 2.21, 2.10, 1.98, 1.92 (5 s, 15 H, 5 AcO), 1.78, 1.45 (s, 3H, AcN). Anal. Calcd for $C_{41}H_{49}NO_{21}$ (891.83): C, 55.22; H, 5.54; N, 1.57. Found: C, 55.03; H, 5.38; N, 1.46.

Methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate-(2→3)-1*-O-*acetyl-6-azido-2,4-di*-O-*benzoyl-6-deoxy*-β-D-*galactopyranose* (**7**).—To a solution of **5** (460 mg, 0.478 mmol) in toluene (3 mL) were added acetic anhydride (0.61 mL, 6.5 mmol) and $BF_3 \cdot OEt_2$ (0.12 mL, 0.45 mmol), and the mixture was stirred for 3 h at room temperature. Workup as described for **6** gave **7** (375 mg, 84%) as an amorphous mass: $[\alpha]_D$ +53.0° (*c* 1.7, $CHCl_3$); IR (film) 3350, 2950, 2130, 1750, 1680, 700 cm^{-1}; ^1H NMR ($CDCl_3$):δ, 7.28–8.14 (m, 10 H, 2 Ph), 6.09 (d, 1 H, H-1a), 5.47 (dd, 1 H, $J_{1,2}$ 8.2 Hz, H-2a), 4.98 (dd, 1 H, $J_{2,3}$ 10.2 Hz, $J_{3,4}$ 3.3 Hz, H-3a), 4.79 (m, 1 H, H-4b), 4.34 (dd, 1 H, J_{gem} 12.2, $J_{8,9'}$ 2.2 Hz, H-9′), 3.9 (s, 3 H, COO*Me*), 4.3 Hz, H-3b*eq*), 2.49 (dd, 1 H, J_{gem} 12.6, $J_{3eq,4}$, 2.22, 2.11, 1.99, 1.92 (5 s, 15 H, 5 AcO), 1.78, 1.48 (s, 3 H, AcN). Anal. Calcd for $C_{42}H_{48}N_4O_{20}$ (928.85): C, 54.31; H, 5.21; N, 6.03. Found: C, 54.28; H, 5.16; N, 5.78.

Methyl (methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di*-O-*benzoyl-6*-O-*methyl-1-thio*-β-D-*galactopyranoside* (**8**).—To a solution of **6** (130 mg, 0.145 mmol) in toluene (2 mL) was added (methylthio)trimethylsilane (TMS·SMe; 49.8 μL, 0.35 mmol) and $BF_3 \cdot OEt_2$ (37.8 μL, 0.14 mmol), and the mixture was stirred for 2.5 h at 50 °C and extracted with CH_2Cl_2. The extract was successively washed with M Na_2CO_3 and water, dried (Na_2SO_4), and concentrated. Column chromatography (30:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **8** (124 mg, 94%) as an amorphous mass:$[\alpha]$D +59.1° (*c* 2.4, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.31–8.16 (m, 10 H, 2 Ph), 5.59 (m, 1 H, H-8), 5.52 (t, 1 H, $J_{1,2} = J_{2,3} =$ 9.9 Hz, H-2a), 5.31 (d, 1 H, $J_{3,4}$ 2.9 Hz, H-4a), 5.21 (dd, 1 H, $J_{6,7}$ 2.6, $J_{7,8}$ 9.2 Hz, H-7), 4.86 (dd, 1 H, $J_{2,3}$ 9.8 Hz, $J_{3,4}$ 3.0 Hz, H-3a), 4.78 (d, 1 H, $J_{1,2}$ 9.7 Hz, H-1a), 4.34 (dd, 1 H, J_{gem} 12.5, $J_{8,9'}$ 2.3 Hz, H-9′), 3.91 (s, 3 H, COO*Me*), 3.32 (s, 3 H, MeO), 2.47 (dd, 1, H, J_{gem} 12.8, $J_{3eq,4}$ 4.6 Hz, H-3b*eq*), 2.26 (s, 3 H, SMe), 2.22, 2.08, 1.92, 1.78 (4 s, 12 H, 4 AcO), 1.47 (s, 3 H, AcN). Anal. Calcd for $C_{40}H_{49}NO_{19}S$ (879.89): C, 54.60; H, 5.61; N, 1.59. Found: C, 54.46; H, 5.48; N,1.34.

Methyl (methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto*-2- nonulopyranosylonate)-(2→3)-azido-2,4-di*-O-*benzoyl-6-deoxy-1-thio*-β-D-*galactopyranoside* (**9**).—To a solution of **7** (350 mg, 0.377 mmol) in toluene (2.5 mL) was added TMS·SMe (0.14 mL, 0.99 mmol) and $BF_3 \cdot OEt_2$ (0.11 mL, 0.37 mmol), and the mixture was stirred for 7.5 h at 50 °C. Workup as described for **8** gave **9** (261 mg, 75%) as an amorphous mass $[\alpha]_D$ +55.0° (*c* 5.1, $CHCl_3$); IR (film) 3350, 2950, 2130, 1750, 1680, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.24–8.24 (m, 10 H, 2 Ph), 5.60 (m, 1 H, H-8), 5.55 (t, 1 H, H-2a), 4.79 (dd, 1 H, $J_{2,3}$ 9.8 Hz, $J_{3,4}$ 3.3 Hz, H-3a), 4.78 (d, 1 H, $J_{1,2}$ 9.9 Hz, H-1a), 4.35 (dd, 1 H, J_{gem} 12.5, $J_{8,9'}$ 2.4 Hz, H-9′), 3.88 (s, 3 H, COO*Me*), 2.52 (dd, 1 H, J_{gem} 12.5, $J_{3eq,4}$ 4.5 Hz, H-3b*eq*), 2.25 (s, 3 H, SMe), 2.22, 2.09, 1.91, 1.78 (4 s, 12 H, 4 AcO), 1.49 (s, 3 H, AcN). Anal. Calcd for $C_{41}H_{48}N_4O_{18}S$ (916.91): C, 53.71; H, 5.28; N, 6.11. Found: C, 53.70; H, 5.18; N, 5.96.

2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di*-O-*benzoyl-6*-O-*methyl*-β-D-*galactopyranosyl-(1→4)-2-acetamido-6*-O-*benzyl-2-deoxy-3*-O-*(4-methoxybenzyl)*-β-D-*glucopyranosyl-(1→3)-2,4,6-tri*-O-*benzyl*-β-D-*galactopyranosyl-(1→4)-2,3,6-tri*-O-*benzyl*-β-D-*glucopyranoside* (**11**).—To a solution of **8** (110 mg, 0.125 mmol) and **10** (118 mg, 84 μmol) in dry CH_2Cl_2 (3 mL) was added powdered 4Å (MS 500 mg), and the mixture was stirred for 6 h at room temperature, then cooled to 0 °C. Dimethyl(methylthio)sulfonium triflate (DMTST; 165 mg, 0.64 mmol) was added to the mixture, which was stirred for 21 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 (40:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **11** (170 mg, 90%) as an amorphous mass: $[\alpha]_D$ 41 +7.3° (*c* 1.1, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.05–8.24 (m, 49 H, 9 Ph, MeO*Ph*, 5.67 (m, 1 H, H-8), 5.46 (t, 1 H, $J_{2,3}$ 10.9 Hz, H-2d), 5.22 (dd, 1 H, $J_{6,7}$ 2.1, $J_{7,8}$ 8.1 Hz, H-7), 4.59 (d, 1 H, $J_{1,2}$ 10.9 Hz, H-1d), 3.89 (s, 3 H, COO*Me*), 3.64 (s, 3 H, *Me*OPh), 3.39 (s, 3 H, MeO), 2.43 (dd, 1 H, J_{gem} 12.3, $J_{3eq,4}$ 4.4 Hz, H-3e*eq*), 2.17, 1.98, 1.92, 1.78 (4 s, 12 H, 4 AcO), 1.49, 1.22 (2 s, 6 H, 2 AcN), 0.99 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{123}H_{144}N_2O_{36}Si$ (2254.57): C, 65.53; H, 6.44; N, 1.24. Found: C, 65.26; H, 6.32; N, 0.95.

2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-6-azido-*

*2,4-di-*O*-benzoyl-6-deoxy-*β*-*D*-galactopyranosyl-1→4)-2-acetamido-6-*O*-benzyl-2-deoxy-3-*O*-(4-methoxybenzyl)-*β*-*D*-glucopyranosyl-(1→3)-2,4,6-tri-*O*-benzyl-*β*-*D*-galactopyranosyl-(1→4)-2,3,6-tri-*O*-benzyl-*β*-*D*-glucopyranoside* (**12**).—Glycosylation of **10** (102 mg, 72 μmol) with **9** (100 mg, 0.109 mmol) in dry CH_2Cl_2 (3 mL) in the presence of DMTST (141 mg, 0.55 mmol) and 4Å MS (500 mg) for 14 h at 0 °C, then workup as described for **11**, gave **12** (137 mg, 83%) as an amorphous mass: $[\alpha]_D$ +11.6° (*c* 3.2, $CHCl_3$); IR (film) 3350, 2950, 2130, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.08–8.31 (m, 49 H, 9 Ph, MeO*Ph*), 5.67 (m, 1 H, H-8), 5.45 (t, 1 H, $J_{2,3}$ 10.6 Hz, H-2d), 4.64 (d, 1 H, $J_{1,2}$ 10.6 Hz, 3.87 (s, 3 H, COO*Me*), 3.67 (s, 3 H, *Me*OPh), 2.46 (dd, 1 H, J_{gem} = 12.4, $J_{3eq,4}$ = 4.4 Hz, H-3e*eq*), 2.19 (4 s, 12 H, 4 AcO), 1.98, 1.92, 1.79, 1.49 (2 s, 6 H, 2 AcN), 1.33, 0.92 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{122}H_{141}N_5O_{35}Si$ (2265.56): C, 64.68; H, 6.27; N, 3.09. Found: C, 64.51; H, 6.15; N, 3.09.

*2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy–*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di-*O*-benzoyl-6-*O*-methyl-*β*-*D*-galactopyranosyl-(1→4)-2-acetamido-6-*O*-benzyl-2-deoxy-*β*-*D*-glucopyranosyl-(1→3)-2,4,6-tri-*O*-benzyl-*β*-*D*-galactopyranosyl-(1→4)-2,3,6-tri-*O*-benzyl-*β*-*D*-glucopyranoside* (**13**).—To a solution of **11** (167 mg, 74 μmol) in dry CH_2Cl_2 (3 mL) were added $SnCl_2$ (0.7 mg, 3.7 μmol) and anisole (12 μL, 0.11 mmol), and the mixture was cooled to 0 °C. Trimethylchlorosilane (TMSCl; 28 μL, 0.22 mmol) was added to the mixture, which was stirred for 7 h at 20 °C and extracted with CH_2Cl_2. The extract was washed with M Na_2CO_3 and water, dried (Na_2SO_4) and concentrated. Column chromatography (40:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **13** (142 mg, 90%) as a syrup: $[\alpha]_D$ +38.3° (*c* 3.4, $CHCl_3$); IR (film) 3550, 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.02–8.28 (m, 45 H, 9 Ph), 5.59 (m, 1 H, H-8), 5.20 (dd, 1 H, $J_{6,7}$ 2.4 $J_{7,8}$ 8.4 Hz, H-7), 4.66 (d, 1 H, $J_{1,2}$ 10.6 HZ, H-1d), 4.47 (dd, 1 H, J_{gem} 12.5, $J_{8,9}$ 2.4 Hz, H-9′), 3.87 (s, 3 H, COO*Me*), 3.41 (s, 3 H, MeO), 2.46 (dd, 1 H, J_{gem} 12.4, $J_{3eq,4}$ 4.3 Hz, H-3e*eq*), 2.21, 2.03, 1.91, 1.78 (4 s, 12 H, 4 AcO), 1.71, 1.43 (2 s, 6 H, 2 AcN), 1.00 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{115}H_{136}N_2O_{35}Si$ (2134.42): C, 64.71; H, 6.42; N, 1.31. Found: C, 64.43; H, 6.36; N, 1.07.

*2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-6-azido-2,4-di-*O*-benzoyl-6-deoxy-*β*-*D*-galactopyranosyl-(1→4)-2-acetamido-6-*O*-benzyl-2-deoxy-*β*-*D*-glucopyranosyl-(1→3)-2,4,6-tri-*O*-benzyl-*β*-*D*-galactopyranosyl-(1→4)-2,3,6-tri-*O*-benzyl-*β*-*D*-glucopyranoside* (**14**).—To a solution of **12** (24 mg, 11 μmol) in dry CH_2Cl_2 (3 mL) were added $SnCl_2$ (0.1 mg, 0.5 μmol) and anisole (1.7 μL, 16 μmol), and the mixture was cooled to 0 °C. TMSCl (4 μL, 32 μmol) was added to the mixture, which was stirred for 7 h at 20 °C. Workup as described for **13** gave **14** (22.6 mg, 96%) as a syrup: $[\alpha]_D$ +27.2° (*c* 0.4, $CHCl_3$); IR (film) 3550, 3350, 2950, 2130, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.09–8.33 (m, 45 H, 9 Ph), 5.63 (m, 1 H, H-8), 5.44 (dd, 1 H, $J_{2,3}$ 8.1 Hz, H-2d), 4.82 (d, 1 H, $J_{1,2}$ 8.9 Hz, H-1d), 3.87 (s, 3 H, COO*Me*), 2.59 (dd, 1 H, J_{gem} 12.8, $J_{3eq,4}$ 4.4 Hz, H-3e*eq*), 2.22, 2.03, 1.96, 1.78 (4 s, 12 H, 4 AcO), 1.54, 1.22 (2 s, 6 H, 2 AcN), 1.00 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{114}H_{133}N_5O_{34}Si$ (2145.41): C, 63.82; H, 6.25; N, 3.26. Found: C, 63.52; H, 6.13; N, 3.06.

*2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di-*O*-benzoyl-6-*O*-methyl-*β*-*D*-galactopyranosyl-(1→4)-[2,3,4-tri-*O*-benzyl-*α*-*L*-fucopyranosyl-(1→3)]-2-acetamido-6-*O*-benzyl-2-deoxy-*β*-*D*-glucopyranosyl-(1→3)-2,4,6-tri-*O*-benzyl-*β*-*D*-galactopyranosyl-(1→4)-2,3,6-tri-*O*-benzyl-*β*-*D*-glucopyranoside* (**16**).—To a solution of **13** (220 mg, 0.10 mmol) and **15** (81.4 mg, 0.15 mmol) in dry benzene (4 mL) was added powdered 4Å MS (500 mg), and the mixture was stirred for 5 h at room temperature, then cooled to 0 °C. *N*-Iodosuccinimide (NIS; 104 mg, 0.46 mmol) and trifluoromethanesulfonic acid (TfOH; 11 μL, 0.12 mmol), were added to the mixture, which was stirred for 7 h at 7 °C, then neutralized with Et_3N. The solids were filtered off and washed with CH_2Cl_2. The combined filtrate and washings was successively washed with M Na_2CO_3 and water, dried (Na_2SO_4) and concentrated. Column chromatography (45:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **16** (245 mg, 96%) as a syrup: $[\alpha]_D$ −19.7° (*c* 2.3, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.14–8.20 (m, 60 H, 12 Ph), 5.55 (m, 1 H, H-8), 5.24 (dd, 1 H, $J_{6,7}$ 2.4, $J_{7,8}$ 8.4 Hz, H-7), 3.84 (s, 3 H, COO*Me*), 3.45 (s, 3 H, MeO), 2.46 (dd, 1 H, J_{gem} 12.4, $J_{3eq,4}$ 4.3 Hz, H-3e*eq*), 2.17, 1.97, 1.92, 1.79 (4 s, 12 H, 4 AcO), 1.46, 1.40 (2 s, 6 H, 2 AcN), 1.20 (d, 3 H, $J_{5,6}$ 6.4 Hz, H-6f), 1.02 (m, 2 H,

$Me_3SiCH_2CH_2$). Anal. Calcd for $C_{142}H_{164}N_2O_{39}Si$ (2550.94): C, 66.86; H, 6.48; N, 1.10. Found: C, 66.71; H, 6.36; N, 0.87.

*2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto*-2-nonulopyranosylonate)-(2→3)-6-azido-2,4-di-*O*-benzoyl-6-deoxy-β-D-galactopyranosyl-(1→4)-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→3)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranosyl-(1→3)-2,4,6-tri-*O*-benzyl-β-D-galactopyranosyl-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside* (**17**).—To a solution of **14** (148 mg, 69.1 μmol) and **15** (54.5 mg, 0.10 mmol) in dry benzene (4 mL) was added powdered 4Å MS (500 mg), and the mixture was stirred for 5 h at room temperature, then cooled to 0 °C. NIS (69.8 mg, 0.31 mmol) and TfOH (7.3 μL, 83 μmol) were added to the mixture, which was stirred for 7 h at 7 °C, then neutralize with Et_3N. Workup as described for **16** gave **17** (158 mg, 89%) as a syrup: $[\alpha]_D$ −9.4° (*c* 3.1, $CHCl_3$); IR (film) 3350, 2950, 2130, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.01–8.23 (m, 60 H, 12 Ph), 5.63 (m, 1 H, H-8), 5.20 (t, 1 H, H-2d), 4.49 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1d), 3.81 (s, 3 H, COO*Me*), 2.49 (dd, 1 H, J_{gem} 12.8, $J_{3eq,4}$ 4.6 Hz, H-3e*eq*), 2.19, 1.96, 1.92, 1.78 (4 s, 12 H, 4 AcO), 1.46, 1.22 (2 s, 6 H, 2 AcN) (d, 3 H, $J_{5,6}$ 6.4 Hz, H-6f), 1.18, 1.01 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{141}H_{161}N_5O_{38}Si$ (2561.92): C, 66.10; H, 6.33; N, 2.73. Found: C, 66.04; H, 6.30; N, 2.52.

*2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto*-2-nonulopyranosylonate)-(2→3)-2,4-di-*O*-benzoyl-6-deoxy-6-trifluoroacetamido-β-D-galactopyranosyl-(1→4)-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→3)]-2-acetamido-6-*O*-benzyl-2-deoxy-β-D-glucopyranosyl-(1→3)-2,4,6-tri-*O*-benzyl-β-D-galactopyranosyl-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside* (**18**).—To a solution of **17** (135 mg, 52 μmol) in benzene (1.5 mL) were added triphenylphosphine (55.3 mg, 0.21 mmol) and water (0.1 mL), and the mixture was stirred for 5.5 h at room temperature. The mixture was concentrated, and the residue was treated with trifluoroacetic anhydride (30 μL, 0.21 mmol) in CH_2Cl_2 (2 mL) and pyridine (0.4 mL) for 6 h at 0 °C. After completion of the reaction, the mixture was diluted with CH_2Cl_2 (50 mL) successively washed with M Na_2CO_3, 2 M HCl and water, dried (Na_2SO_4), and concentrated. Column chromatography of the residue on silica gel gave **18** (63.5 mg, 46%) as an amorphous mass: $[\alpha]_D$ −13.5° (*c* 1.4, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.08–8.21 (m, 60 H 12 Ph), 5.65 (m, 1 H, H-8), 3.71 (s, 3 H, COO*Me*), 2.41 (dd, 1 H, J_{gem} 12.6, $J_{3eq,4}$, 14.7 Hz, H-3e*eq*), 2.11, 1.92, 1.77, 1.58 (4 s, 12 H, 4 AcO), 1.38, 1.26 (2 s, 6 H, 2 AcN) (d, 3 H, $J_{5,6}$ 6.3 Hz, H-6f), 1.16, 1.01 (m, 2 H, $Me_3SiCH_2CH_2$), Anal. Calcd for $C_{143}H_{162}F_3N_3O_{39}Si$ (2631.93): C, 65.26; H, 6.20; N, 1.60. Found: C, 65.06; H, 6.03; N, 1.38.

*2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto*-2-nonulopyranosylonate)-(2→3)-2,4-di-*O*-benzoyl-6-*O*-methyl-β-D-galactopyranosyl-(1→4)-[α-L-fucopyranosyl-(1→3)]-2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→)-β-D-galactopyranosyl-(1→4)-β-D-glucopyranoside* (**19**).—A solution of **16** (103 mg, 40 μmol) in HOAc (2 mL) was hydrogenated over 10% Pd–C (150 mg) for 48 h at 40 °C, then filtered and concentrated. Column chromatography (15:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **19** (34.9 mg, 53%) as an amorphous mass: $[\alpha]_D$ −18.7° (*c* 0.7, 1:1 $CHCl_3$–MeOH); IR (film) 3550, 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR (CD_3OD): δ 7.47–8.23 (m, 10 H, 2 Ph),5.62 (m, 1 H, H-8), 5.32 (d, 1 H, $J_{5,NH}$ 9.9 Hz, NH), 5.05 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1d), 4.55 (d, 1 H, $J_{1,2}$ = 3.1 Hz, H-1f), 4.43 (dd, 1 H, J_{gem} 12.5, $J_{8,9}$ 2.4 Hz, H-9′), 3.80 (s, 3 H, COO*Me*), 3.33 (s, 3 H, MeO), 2.42 (dd, 1 H, J_{gem} 12.8, $J_{3eq,4}$, 4.6 Hz, H-3e*eq*), 2.21, 2.06, 1.92, 1.84 (4 s, 12 H, 4 AcO), 1.70, 1.53 (2 s, 6 H, 2 AcN), 1.17 (d, 3 H, $J_{5,6}$ 5.7 Hz, H-6f), 0.94 (m, 2 H, $Me_3SiCH_2CH_2$), Anal. Calcd for $C_{72}H_{104}N_2O_{39}Si$ (1649.69): C, 52.42; H, 6.35; N, 1.70. Found: C, 52.28; H, 6.16; N, 1.65.

*2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto*-2-nonulopyranosylonate)-(2→3)-6-acetamido-2,4-di-*O*-benzoyl-6-deoxy-β-D-galactopyranosyl-(1→4)-[α-L-fucopyranosyl-(1→3])-2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→3)-β-D-galactopyranosyl-(1→4)-β-D-glucopyranoside* (**20**).—A solution of **17** (49.0 mg, 19 μmol) in HOAc (2 mL), EtOH (2 mL) and Ac_2O (0.2 mL) was hydrogenated over 10% Pd–C (80 mg) for 48 h at 40 °C, then filtered and concentrated. Column chromatography (12:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **20** (18.1 mg, 57%) as an amorphous mass: $[\alpha]_D$ −14.3° (*c* 0.3, 1:1 $CHCl_3$–MeOH); IR (film) 3550, 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR (CD_3OD): δ 7.44–8.21 (m, 10 H, 2 Ph), 5.67 (m, 1 H, H-8), 5.24 (d, 1 H, $J_{5,NH}$ 9.8 Hz, NH), 5.08 (d, 1 H, $J_{1,2}$ 7.7 Hz, H-1d), 4.41 (dd, 1 H, J_{gem} 12.4, $J_{8,9'}$ 2.4 Hz, H-9′) 3.78 (s, 3 H, COO*Me*), 2.39 (dd, 1 H, J_{gem} 2.8, $J_{3eq,4}$, 1.1 Hz, H-3e*eq*) 2.06, 2.00, 1.95, 1.92 (4 s, 12 H, 4 AcO), 1.81, 1.70, 1.42 (3 s, 9 H, 3AcN), 1.26 (d, 3 H, $J_{5,6}$ 5.3 Hz, H-6f), 0.89 (m, 2 H, $Me_3SiCH_2CH_2$), Anal. Calcd for $C_{73}H_{105}N_3O_{39}Si$ (1676.71): C, 52.29; H, 6.31; N, 2.51. Found: C, 52.03; H, 6.02; N, 2.41.

*2-(Trimethylsilyl)ethyl 5-acetamido-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonic acid-(2→3)-6-*O*-methyl-*β-D*galactopyranosyl-(1→4)-[*α-L-*fucopyranosyl(1→3)]-2-acetamido-2-deoxy-*β-D-*glucopyranosyl-(1→3)-*β-D-*galactopyranosyl-(1→4)-*β-D-*glucopyranoside* (**21**).—To a solution of **19** (33.2 mg, 20 μmol) in MeOH (2 mL) and THF (1 mL) was added NaOMe (10 mg), and the mixture was stirred for 48 h at 40 °C, and for another 24 h after addition of water (0.5 mL). The mixture was neutralized with Amberlite IR-120 (H^+) resin and filtered. The resin was washed with MeOH, and the combined filtrate and washings were concentrated. Column chromatography (MeOH) of the residue on Sephadex LH-20 (40 g) gave **22** (25.1 mg, 99%) as an amorphous mass: $[\alpha]_D$ −29.4° (*c* 0.5, MeOH); ^{1}H NMR (CD_3OD): δ 3.35 (s, 3 H, MeO), 2.38 (dd, 1 H, J_{gem} 12.7, $J_{3eq,4}$ 4.6 Hz, H-3e*eq*), 1.98, 1.94 (2 s, 6 H, 2 AcN), 1.26 (d, 3 H, $J_{5,6}$ 5.7 Hz, H-6f), 0.97 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{49}H_{86}N_2O_{33}Si$ (1259.29): C, 46.74; H, 6.88; N, 2.22. Found: C, 46.71; H, 6.85; N, 2.09.

*2-(Trimethylsilyl)ethyl 5-acetamido-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonic acid-(2→3)-6-acetamido-6-deoxy-*β-D-*galactopyranosyl-(1→4)-[*α-L-*fucopyranosy-(1→3)]-2-acetamido-2-deoxy-*β-D-*glucopyranosyl-(1→3)-*β-D-*galactopyranosyl-(1→4)-*β-D-*glucopyranoside* (**22**).—To a solution of **20** (20.1 mg, 12 μmol) in MeOH (2 mL) and THF (1 mL) was added NaOMe (10 mg), and the mixture was stirred for 48 h at 40 °C, and for another 24 h after addition of water (0.5 mL). Workup as described for **21** gave **22** (14.9 mg, 98%) as an amorphous mass: $[\alpha]_D$ −22.1° (*c* 0.2, MeOH); ^{1}H NMR (CD_3OD): δ 5.02 (d, 1 H, $J_{5,NH}$ 0.1 Hz, NH), 1.98, 1.95, 1.94 (3 s, 9 H, 3 AcN), 1.19 (d, 3 H, $J_{5,6}$ 5.6 Hz, H-6f), 0.94 (m, 2 H, $Me_3SiCH_2CH_2$. Anal. Calcd for $C_{50}H_{87}N_3O_{33}Si$ (1286.32): C, 46.69; H, 6.82; N, 3.27. Found: C, 46.59; H, 6.54; N, 3.02.

*2-(Trimethylsilyl)ethyl 5-acetamido-3,5-dideoxy-*D-glycero-α-D-*galacto-2-nonulopyranosylonic acid-(2→3)-6-azido-6-deoxy-*β-D-*galactopyranosyl-(1→4)-[2,3,4-tri-*O*-benzyl-*α-L-*fucopyranosyl-(1→3)]-2-acetamido-6-*O*-benzyl-2-deoxy-*β-D-*glucopyranosyl-(1→3)-2,4,6-tri-*O*-benzyl-*β-D-*galactopyranosyl-(1→4)-2,3,6-tri-*O*-benzyl-*β-D-*glucopyranoside* (**23**).—To a solution of **17** (46.1 mg, 18 μmol) in MeOH (2 mL) and THF (1 mL) was added NaOMe (10 mg), and the mixture was stirred for 48 h at 40 °C, then water (0.5 mL) was added. After completion of the reaction (24 h), the mixture was neutralized with Amberlite IR-120 (H^+) resin and filtered. The resin was washed with MeOH, and combined filtrate and washings was concentrated. Column chromatography (5:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **23** (35.2 mg, 91%) as an amorphous mass: $[\alpha]_D$ −29.1° (*c* 0.7, 1:1 $CHCl_3$–MeOH); IR (film) 3550, 3350, 2950, 2130, 1750, 1680, 860, 840, 700 cm^{-1}; ^{1}H NMR (CD_3OD): δ 6.92–7.51 (m, 50 H, 10 Ph), 5.47 (d, 1 H, $J_{5,NH}$ 10.1 Hz, NH), 2.47 (dd, 1 H, J_{gem} 12.9, $J_{3eq,4}$ 4.6 Hz, H-3e*eq*), 2.01, 1.68 (2 s, 6 H, 2 AcN), 1.14 (d, 3 H, $J_{5,6}$ 5.7 Hz, H-6f), 0.97 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{118}H_{143}N_5O_{32}Si$ (2171.53): C, 65.27; H, 6.64; N, 3.23. Found: C, 65.19; H, 6.62; N, 3.22.

*2-(Trimethylsilyl)ethyl 5-acetamido-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonic acid-(2→3)-6-amino-6-deoxy-*β-D-*galactopyranosyl-(1→4)-[*α-L-*fucopyranosyl(1→3)]-2-acetamido-2-deoxy-*β-D-*glucopyranosyl-(1→3)-*β-D-*galactopyranosyl-(1→4)-*β-D-*glucopyranoside* (**24**).—A solution of **21** (29.8 mg, 14 μmol) in HOAc (2 mL) was hydrogenated over $Pd(OH)_2$ (150 mg) for 48 h at 40 °C, then filtered and concentrated. Column chromatography (MeOH) of the residue on Sephadex LH-20 (40 g) gave **24** (13.1 mg, 77%) as an amorphous mass: $[\alpha]_D$ −22.7 (*c* 0.2, MeOH); ^{1}H NMR (CD_3OD): δ 2.39 (dd, 1 H, J_{gem} 12.5, $J_{3eq,4}$ 4.2 Hz, H-3e*eq*), 1.96, 1.95 (2 s, 6 H, 2 AcN), 1.18 (d, 3 H, $J_{5,6}$ 6.4 Hz, H-6f), 0.93 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{48}H_{85}N_3O_{32}Si$ (1244.28): C, 46.33; H, 6.89; N, 3.38. Found: C, 46.09; H, 6.79; N, 3.24.

*2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonate)-(2→3)-2,4-di-*O*-benzoyl-6-*O*-methyl-*β-D-*galactopyranosyl-(1→4)]-[2,3,4-tri-*O*-acetyl-*α-L-*fucopyranosyl-(1→3)-2-acetamido-6-*O*-acetyl-2-deoxy-*β-D-*glucopyranosyl-(1→3)-2,4,6-tri-*O*-acetyl-*β-D-*galactopyranosyl-(1→4)-2,3,6-tri-*O*-acetyl-*β-D-*glucopyranoside* (**25**).—A solution of **16** (86.8 mg, 34 μmol) in EtOH (2 mL) and HOAc (2 mL) was hydrogenated over $Pd(OH)_2$ (90 mg) for 24 h at 40 °C, then filtered and concentrated.

The residue was acetylated with Ac_2O (0.5 mL) and pyridine (3 mL) for 24 h at room temperature. The solution was diluted with CH_2Cl_2 (50 mL), and the solution was washed with 2 M HCl and water, dried (Na_2SO_4), and concentrated. Column chromatography (40:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **25** (54.9 mg, 78%) as an amorphous mass: $[\alpha]_D$ −15.6° (*c* 2.3, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.41–8.22 (m, 10 H, 2 Ph), 5.63 (m, 1 H, H-8), 3.88 (s, 3 H, COO*Me*), 3.37 (s, 3 H, MeO), 2.39 (dd, 1 H, J_{gem} 12.2, $J_{3eq,4}$ 4.6 Hz, H-3e*eq*), 1.55–2.22 (16 s, 48 H, 2 AcN, 14 AcO), 1.18 (d, 3 H, $J_{5,6}$ 6.6 Hz, H-6f), 0.94 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{92}H_{124}N_2O_{49}Si$ (2070.06): C, 53.38; H, 6.04; N, 1.35. Found: C, 53.17; H, 5.86; N, 1.28.

*2-(Trimethylsilyl)ethyl (methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-*glycero*-α-*D*-*galacto*-2-nonulopyranosylonate)-(2→3)-6-acetamido-2,4-di-*O*-benzoyl-6-deoxy-β-*D*-galactopyranosyl-(1→4)-[2,3,4-tri-*O*-acetyl-α-*L*-fucopyranosyl-(1→3)]-2-acetamido-6-*O*-acetyl-2-deoxy-β-*D*-glucopyranosyl-(1→3)-2,4,6-tri-*O*-acetyl-β-*D*-galactopyranosyl-(1→4)-2,3,6-tri-*O*-acetyl-β-*D*-glucopyranoside* (**26**).—A solution of **17** (191 mg, 75 μmol) in EtOH (3 mL), HOAc (3 mL) and Ac_2O (0.5 mL) was hydrogenated over $Pd(OH)_2$ (200 mg) for 48 h at 40 °C, then filtered and concentrated. The residue was acetylated with Ac_2O (1 mL) and pyridine (2 mL) for 24 h at room temperature. Workup as described for **25** gave **26** (121 mg, 77%) as an amorphous mass: $[\alpha]_D$ −16.4° (*c* 2.4, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.41–8.22 (m, 10 H, 2 Ph), 5.67 (m, 1 H, H-8), 4.48 (d, 1 H, $J_{1,2}$ 3.4 Hz, H-1f), 3.88 (s, 3 H, COO*Me*), 2.36 (dd, 1 H, J_{gem} 12.7, $J_{3eq,4}$ 4.7 Hz, H-3e*eq*), 1.58–2.22 (17 s, 51 H, 3 AcN, 14 AcO), 1.19 (d, 3 H, $J_{5,6}$ 6.6 Hz, H-6f), 0.93 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{93}H_{125}N_3O_{49}Si$ (2097.08): C, 53.27; H, 6.01; N, 2.00. Found: C, 53.25; H, 5.81; N, 1.94.

*2-(Trimethylsilyl)ethyl methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-*glycero*-α-*D*-*galacto*-2-nonulopyranosylonate-(2→3)-2,4-di-*O*-benzoyl-6-deoxy-6-trifluoroacetamido-β-*D*-galactopyranosyl-(1→4)-[2,3,4-tri-*O*-acetyl-α-*L*-fucopyranosyl-(1→3)]-2-acetamido-6-*O*-acetyl-2-deoxy-β-*D*-glucopyranosyl-(1→3)-2,4,6-tri-*O*-acetyl-β-*D*-galactopyranosyl-(1→4)-2,3,6-tri-*O*-acetyl-β-*D*-glucopyranoside* (**27**).—A solution of **18** (63.5 mg, 24 μmol) in EtOH (2 mL) and HOAc (2 mL) was hydrogenated over $Pd(OH)_2$ (65 mg) for 24 h at 40 °C, then filtered and concentrated. The residue was acetylated with Ac_2O (1 mL) and pyridine (1 mL) for 24 h at room temperature. Workup as described for **25** gave **26** (41.5 mg, 80%) as an amorphous mass: $[\alpha]_D$ −16.3° (*c* 1.0, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 860, 840, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.28–8.18 (m, 10 H, 2 Ph),5.61 (m, 1 H, H-8), 3.78 (s, 3 H, COO*Me*), 2.38 (dd, 1 H, J_{gem} 12.5, $J_{3eq,4}$ 4.6 Hz, H-3e*eq*), 1.43–2.18 (16 s, 48 H, 2 AcN, 14 AcO), 1.17 (d, 3 H, $J_{5,6}$ 6.7 Hz, H-6f), 0.91 (m, 2 H, $Me_3SiCH_2CH_2$). Anal. Calcd for $C_{93}H_{122}F_3N_3O_{49}Si$ (2151.05): C, 51.93; H, 5.72; N, 1.95. Found: C, 51.76; H, 5.67; N, 1.69.

*Methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-*glycero*-α-*D*-*galacto*-2-nonulopyranosylonate-(2→3)-2,4-di-*O*-benzoyl-6-*O*-methyl-β-*D*-galactopyranosyl-(1→4)-[2,3,4-tri-*O*-acetyl-α-*L*-fucopyranosyl-(1→3)]-2-acetamido-6-*O*-acetyl-2-deoxy-β-*D*-glucopyranosyl-(1→3)-2,4,6-tri-*O*-acetyl-β-*D*-galactopyranosyl-(1→4)-2,3,6-tri-*O*-acetyl-β-*D*-glucopyranosyl trichloroacetimidate* (**28**).—To a solution of **25** (97.3 mg, 47 μmol) in CH_2Cl_2 (1.2 mL), cooled to 0 °C, was added CF_3COOH (0.7 mL), and the mixture was stirred for 3 h at room temperature and concentrated. The product was purified by column chromatography on silica gel with 35:1 CH_2Cl_2–MeOH to give the 1-hydroxy compound (83.0 mg). To a solution of the residue in CH_2Cl_2 (1 mL) cooled to 0 °C were added trichloroacetonitrile (0.13 mL, 1.3 mmol) and DBU (6.3 μL, 42 μmol). The mixture was stirred for 2 h at 0 °C, and the progress of the reaction was monitored by TLC. After completion of the reaction, the mixture was concentrated. Column chromatography (30:1 CH_2Cl_2–MeOH) of the residue on silica gel gave **28** (80.1 mg, 81%) as an amorphous mass: $[\alpha]_D$ +10.2° (*c* 0.8, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 8.65 (s, 1 H, C=NH), 7.28–8.22 (m, 10 H, 2 Ph), 6.43 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1a), 5.68 (m, 1 H, H-8), 3.88 (s, 3 H, COO*Me*), 3.37 (s, 3 H, MeO), 2.39 (dd, 1 H, J_{gem} 12.6, $J_{3eq,4}$ 4.5 Hz, H-3e*eq*), 1.59–2.24 (16 s, 48 H, 2 AcN, 14 AcO), 1.18 (d, 3 H, $J_{5,6}$ 6.3 Hz, H-6f). Anal. Calcd for $C_{89}H_{112}Cl_3N_3O_{49}Si$ (2114.21): C, 50.56; h, 5.34; N, 1.99. Found: C, 50.30; h, 5.28; N, 1.80.

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

deoxy-β-D-glucopyranosyl-(1→3)-2,4,6-tri-O-acetyl-β-D-galactopyranosyl-(1→4)-2,3,6-tri-O-acetyl-β-D-glucopyranosyl trichloroacetimidate (**29**).—Selective removal of the 2-(trimethylsilyl)ethyl group in **26** (62.1 mg, 30 μmol) with CF_3COOH (0.7 mL) in CH_2Cl_2 (1 mL) for 2 h at room temperature, and subsequent reaction of the product with trichloroacetonitrile (83 μL, 0.83 mmol) in CH_2Cl_2 (1 mL) in the presence of DBU (4.1 μl, 27 μmol) for 2 h at 0 °C as described for **28**, gave **29** (56.5 mg, 88%) as an amorphous mass: $[\alpha]_D$ +1.9° (*c* 1.1, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 700 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 8.65 (s, 1 H, C=NH), 7.28–8.20 (m, 10 H, 2 Ph), 6.47 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1a), 5.62 (m, 1 H, H-8), 5.19 (dd, $J_{6,7}$ 2.5 Hz, $J_{7,8}$ 8.4 Hz, H-7), 3.86 (s, 3 H, COO*Me*), 2.34 (dd, 1 H, J_{gem} 12.8, $J_{3eq,4}$ 4.5 Hz, H-3e*eq*), 1.88–2.21 (17 s, 51 H, 3 AcN, 14 AcO), 1.19 (d, 3 H, $J_{5,6}$ 6.4 Hz, H-6f). Anal. Calcd for $C_{90}H_{113}Cl_3N_4O_{49}Si$ (2141.23): C, 50.48; H, 5.32; N, 2.62. Found: C, 50.47; H, 5.27; N, 2.36.

*Methyl 5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate-(2→3)-2,4-di-O-benzoyl-6-deoxy-6-trifluoroacetamido-β-D-galactopyranosyl-(1→4)-[2,3,4-tri-O-acetyl-α-L-fucopyranosyl-(1→3)]-2-acetamido-6-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→3)-2,4,6-tri-O-acetyl-β-D-galactopyranosyl-(1→4)-2,3,6-tri-O-acetyl-β-D-glucopyranos trichloroacetimidate* (**30**).—Selective removal of the 2-(trimethylsilyl) ethyl group in **27** (41.1 mg, 19 μmol) with CF_3 COOH (0.7 mL) in CH_2Cl_2 (1 mL) for 2 h at room temperature, and subsequent reaction of the product with trichloroacetonitrile (63 μL, 0.63 mmol) in CH_2Cl_2 (0.7 mL) in the presence of DBU (2.8 μL, 18 μmol) for 1.5 h at 0 °C as described for **28** gave **30** (35.2 mg, 84%) as an amorphous mass: $[\alpha]_D$ +4.9° (*c* 0.6, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 700 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 8.65 (s, 1 H, C=NH), 7.22–8.21 (m, 10 H, 2 Ph), 6.45 (d, 1 H, $J_{1,2}$ 3.8 Hz, H-1a), 5.60 (m, 1 H, H-8), 3.88 (S, 3 H, COO*Me*), 2.36 (dd, 1 H, J_{gem} 12.7, $J_{3eq,4}$ 4.6 Hz, H-3e*eq*), 1.83–2.20 (16 s, 48 H, 2 AcN, 14 AcO), 1.19 (d, 3 H, $J_{5,6}$ 6.6 Hz, H-6f). Anal. Calcd for $C_{90}H_{110}Cl_3F_3N_4O_{49}Si$ (2195.20): C, 49.24; H, 5.05; N, 2.55. Found: C, 49.08; H, 4.82; N, 2.55.

*Methyl 5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate-(2→3)-2,4-di-O-benzoyl-6-O-methyl-β-D-galactopyranosyl-(1→4)-[2,3,4-tri-O-acetyl-α-L-fucopyranosyl-(1→3)]-2-acetamido-6-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→3)-2,4,6-tri-O-acetyl-β-D-galactopyranosyl-(1→4)-(2,3,6-tri-O-acetyl-β-D-glucopyranosyl)-(1→1)-(2S,3R,4E)-2-azido-3-O-(tert-butyldiphenylsilyl)-4-octadecene-1,3-diol* (**32**).—To a solution of **28** (37.9 mg, 18 μmol) and (2*S*,3*R*,4*E*)-2-azido-3-*O*-(*tert*-butyldiphenylsilyl)-4-octadecene-1,3-diol (**31**; 20.2 mg, 36 μmol) in dry CH_2Cl_2 (0.5 mL) was added 4Å MS (AW-300, 300 mg), and the mixture was stirred for 12 h at room temperature, then cooled to 0 °C. Trimethylsilyl trifluoromethanesulfonate (TMSOTf, 1 μL, 5.2 μmol) was added, and the mixture was stirred for 24 h at 0 °C. The solids were filtered off and washed with CH_2Cl_2. The combined filtrate and washings were washed with M Na_2CO_3 and water, dried (Na_2SO_4) and concentrated. Column chromatography of the residue on silica gel gave **30** (14.8 mg, 33%) as an amorphous mass: $[\alpha]_D$ −10.5° (*c* 0.7, $CHCl_3$); IR (film) 3350, 2950, 2130, 1750, 1680, 700 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 7.16–8.21 (m, 20 H, 4 Ph), 3.81 (s, 3 H, COO*Me*), 3.39 (s, 3 H, MeO), 2.38 (dd, 1 H, J_{gem} 12.7, $J_{3eq,4}$ 4.5 Hz, H-3e*eq*), 1.81–2.22 (16 s, 48 H, 2 AcN, 14 AcO), 1.26 (s, 22 H, 11 CH_2), 0.88 (t, 3 H, J_{Me,CH_2} 6.8 Hz, $MeCH_2$). Anal. Calcd for $C_{121}H_{143}N_5O_{50}Si$ (2495.55): C, 58.24; h, 5.78; N, 2.81. Found: C, 58.07; H, 5.57; N, 2.74.

*Methyl 5-acetamido-4,7,8,9-tetra-O-acetyl-3,5-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosylonate-(2→3)-6-acetamido-2,4-di-O-benzoyl-6-deoxy-β-D-galactopyranosyl-(1→4)-[2,3,4-tri-O-acetyl-α-L-fucopyranosyl-(1→3)]-2-acetamido-6-O-acetyl-2-deoxy-β-D-glucopyranosyl-(1→3)-2,4,6-tri-O-acetyl-β-D-galactopyranosyl-(1→4)-2,3,6-tri-O-acetyl-β-D-glucopyranosyl-(1→1)-(2S,3R,4E)-2-azido-3-O-(tert-butyldiphenylsilyl)-4-octadecene-1,3-diol* (**33**).—Coupling of **31** (26.2 mg, 12 μmol) with **29** (13.6 mg, 24 μmol) in CH_2Cl_2 (0.4 mL) in the presence of TMSOTf (0.2 μL, 1.0 μmol) and 4Å MS (AW-300, 100 mg) as described for **32** gave **33** (18.2 mg, 58%) as an amorphous mass: $[\alpha]_D$ 27.3° (*c* 0.4, $CHCl_3$); IR (film) 3350, 2950, 2130, 1750, 1680, 700 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 7.22–8.24 (m, 20 H, 4 Ph), 5.64 (m, 1 H; H-8), 4.49 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1a), 3.89 (s, 3 H, COO*Me*), 2.39 (dd, 1 H, J_{gem} 12.4, $J_{3eq,4}$ 4.6 Hz, H-3e*eq*), 1.70–2.26 (17 s, 51 H, 3 AcN, 14 AcO), 1.25 (s, 22 H, 11 CH_2), 0.88 (t, 3 H, J_{Me,CH_2} 6.8 Hz, $MeCH_2$). Anal. Calcd for $C_{122}H_{144}N_6O_{50}Si$ (2522.57): C, 58.09; H, 5.75; N, 3.33. Found: C, 57.91; H, 5.56; N, 3.05.

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

tamido-β-D-*galactopyranosyl-(1→4)-[2,3,4-tri*-O-*acetyl*-α-L-*fucopyranosyl-(1→3)]-2-acetamido-6*-O-*acetyl-2-deoxy*-β-D-*glucopyranosyl-(1→3)-2,4,6-tri*-O-*acetyl*-β-D-*galactopyranosyl-(1→4)-2,3,6-tri*-O-*acetyl*-β-D-*glucopyranosyl-(1→1)-(2*S,*3*R,*4*E*)-2-azido-3*-O-*(*tert-*butyldiphenylsilyl)-4-octadecene-1,3-diol* (**34**).—Coupling of **30** (26.0 mg, 12 μmol) with **31** (13.3 mg, 23 μmol) in CH_2Cl_2 (0.4 mL) in the presence of TMSOTf (0.2 μL, 1.1 μmol) and 4Å MS (AW-300, 100 mg) as described for **32** gave **34** (19.8 mg, 65%) as an amorphous mass: $[\alpha]_D$ −17.4 (*c* 0.3, CHCl3); IR (film) 3350, 2950, 2130, 1750, 1680, 700 cmq; ^1H NMR ($CDCl_3$): δ 7.23–8.18 (m, 20 H, 4 Ph), 5.63 (m, 1 H, H-8), 4.40 (d, 1 H, $J_{1,2}$ 7.7 Hz, H-1a), 3.79 (s, 3 H, COO*Me*), 2.38 (dd, 1 H, J_{gem} 2.7, $J_{3eq,4}$ 12.7 Hz, H-3e*eq*), 1.45–2.18 (16 s, 48 H, 2 AcN, 14 AcO), 1.23 (s, 22 H, 11 CH_2), 0.83 (t, 3 H, J_{Me,CH_2} 6.8 Hz, *Me*CH_2). Anal. Calcd for $C_{122}H_{141}F_3N_6O_{50}Si$ (2576.54): C, 56.87; H, 5.52; N, 3.26. Found: C, 56.60; H, 5.49; N, 3.20.

Methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate-(2→3)-2,4-di*-O-*benzoyl-6*-O-*methyl*-β-D-*galactopyranosyl-(1→4)-[2,3,4-tri*-O-*acetyl*-α-L-*fucopyranosyl-(1→3)]-2-acetamido-6*-O-*acetyl-2-deoxy*-β-D-*glucopyranosyl-(1→3)-2,4,6-tri*-O-*acetyl*-β-D-*galactopyranosyl-(1→4)-(2,3,6-tri*-O-*acetyl*-β-D-*glucopyranosyl)-(1→1)-(2*S,*3*R,*4*E*)-3*-O-tert-*butyldiphenylsilyl)-2-octadecamido-4-octadecene-1,3-diol* (**35**).—To a solution of **32** (14.8 mg, 5.9 μmol) in benzene (0.6 mL) and water (25 μL) was added triphenylphosphine (4.6 mg, 18 mmol), and the mixture was stirred for 24 h with the progress of the reaction being monitored by TLC. The mixture was concentrated, and the residue was stirred with octadecanoic acid (5.0 mg, 18 μmol) and 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (WSC, 3.4 mg, 18 μmol) in dry CH_2Cl_2 (0.8 mL) for 24 h at room temperature. The mixture was diluted with CH_2Cl_2 (25 mL), washed with water, dried (Na_2SO_4) and concentrated. Column chromatography (20:1 CH_2Cl_2–MeOH) of the residue gave **35** (13.1 mg, 81%) as an amorphous mass: $[\alpha]_D$ −6.1° (*c* 0.2, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.29–8.19 (m, 20 H, 4 Ph), 3.84 (s, 3 H, COO*Me*), 3.39 (s, 3 H, MeO), 2.35 (dd, 1 H, J_{gem} 12.8, $J_{3eq,4}$ 4.4 Hz, H-3e*eq*),1.82–2.23 (16 s, 48 H, 2 AcN, 14 AcO), 1.25 (s, 52 H, 26 CH_2), 0.89 (t, 6 H, J_{Me,CH_2} 6.9 Hz, 2 *Me*CH_2), Anal. Calcd for $C_{139}H_{199}N_3O_{51}Si$ (2756.18): C, 60.57; H, 7.28; N, 1.52. Found: C, 60.39; H, 7.15; N, 1.41.

Methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate-(2→3)-2,4-di*-O-*benzoyl-6-deoxy-6-trifluoroacetamido*-β-D-*galactopyranosyl-(1→4)-[2,3,4-tri*-O-*acetyl*-α-L-*fucopyranosyl-(1→3)]-2-acetamido-6*-O-*acetyl-2-deoxy*-β-D-*glucopyranosyl-(1→3)-2,4,6-tri*-O-*acetyl*-β-D-*galactopyranosyl-(1→4)-(2,3,6-tri*-O-*acetyl*-β-D-*glucopyranosyl)-(1→1)-(2*S,*3*R,*4*E*)-3*-O-tert-*butyldiphenylsilyl)-2-octadecamido-4-octadecene-1,3-diol* (**36**).—Selective reduction of the azido group in **33** (17.9 mg, 7.1 μmol) with triphenylphosphine (3.7 mg, 14 μmol) in benzene (1 mL) and water (50 μL), followed by coupling of the product with octadecanoic acid (6 mg, 21.3 μmol) in the presence of WSC (1.3 mg, 21.2 μmol) and work up as described for **35** gave **36** (13.8 mg, 70%) as an amorphous mass: $[\alpha]_D$ −24.3 (*c* 0.4, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.24–8.26 (m, 20 H, 4 Ph), 3.88 (s, 3 H, COO*Me*), 2.36 (dd, 1 H, J_{gem} 12.4 $J_{3eq,4}$ 4.4 Hz, H-3e*eq*), 1.67–2.27 (17 s, 51 H, 3 AcN, 14 AcO), 1.27 (s, 52 H, 26 CH_2), 0.88 (t, 6 H, J_{Me,CH_2} 6.8 Hz, 2 *Me*CH_2). Anal. Calcd for $C_{140}H_{200}N_4O_{51}Si$ (2783.20): C, 60.42; H, 7.24; N, 2.01. Found: C, 60.34; H, 7.17; N, 1.92.

Methyl 5-acetamido-4,7,8,9-tetra-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*2-nonulopyranosylonate-(2→3)-2,4-di*-O-*benzoyl-6-deoxy-6-trifluoroacetamido*-β-D-*galactopyranosyl-(1→4)-[2,3,4-tri*-O-*acetyl*-α-L-*fucopyranosyl-(1→3)]-2-acetamido-6*-O-*acetyl-2-deoxy*-β-D-*glucopyranosyl-(1→3)-2,4,6-tri*-O-*acetyl*-β-D-*galactopyranosyl-(1→4)-(2,3,6-tri*-O-*acetyl*-β-D-*glucopyranosyl-(1→1)-(2*S,*3*R,*4*E*)-3*-O-tert-*butyldiphenylsilyl)-2-octadecamido-4-octadecene-1,3-diol* (**37**).—Selective reduction of azido group in **34** (16.7 mg, 6.5 μmol) with triphenylphosphine (5.1 mg, 19 μmol) in benzene (0.6 mL) and water (50 μL), followed by coupling of the product with octadecanoic acid (5.5 mg, 19 μmol) in the presence of WSC (3.7 mg, 19 μmol) and workup as described for **35**, gave **37** (8.8 mg, 48%) as an amorphous mass: $[\alpha]_D$ −11.4° (*c* 0.2, $CHCl_3$); IR (film) 3350, 2950, 1750, 1680, 700 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.24–8.17 (m, 20 H, 4 Ph), 3.78 (s, 3 H, COO*Me*), 2.38 (dd, 1 H, J_{gem} 2.7, $J_{3eq,4}$ 4.4 Hz, H-3e*eq*), 1.41–2.17 (16 s, 48 H, 2 AcN, 14 AcO), 1.24 (s, 52 H, 26 CH_2), 0.83 (t, 6 H, J_{Me,CH_2} 6.8 Hz, 2 $MeCH_2$). Anal. Calcd for $C_{140}H_{197}F_3N_4O_{51}Si$ (2837.17): C, 59.27; H, 7.00; N, 1.97. Found: C, 59.03; H, 6.89; N, 1.69.

5-Acetamido-3,5-dideoxy-D-glycero-α-D-galacto-*2-nonulopyranosylonic acid-(2→3)-6*-O-*methyl*-β-

*D-galactopyranosyl-(1→4)-[α-L-fucopyranosyl-(1→3)]-2-acetamido-β-D-glucopyranosyl-(1→3)-β-D-galactopyranosyl-(1→4)-β-D-glucopyranosyl-(1→1)-(2*S*,3*R*,4*E*)-2-octadecamido-4-octadecene-1,3-diol* (**38**).—To a solution of **35** (8 mg, 2.9 μmol) in MeCN (0.5 mL), cooled to 0 °C, was added M tetrabutylammonium fluoride (TBAF, 80 μL), and the mixture was stirred for 24 h at room temperature, then concentrated. The residue was treated with NaOMe (10 mg) in MeOH (0.5 mL) and THF (0.1 mL) for 24 h at 40 °C, then water (0.1 mL) was added. After completion of the reaction (24 h), the mixture was neutralized with Amberlite IR-120 (H$^+$) resin and filtered. The resin was washed with MeOH, and the combined filtrate and washings were concentrated. Column chromatography (5:4 CHCl$_3$–MeOH) of the residue on Sephadex LH-20 (40 g) gave **38** (5.1 mg, 98%) as an amorphous mass: $[\alpha]_D$ −14.3° (*c* 0.1, 1:1 CHCl$_3$–MeOH); ^{1}H NMR (CDCl$_3$): δ 3.35 (s, 3 H, MeO), 2.01 (2 s, 6 H, 2 AcN), 1.91, 1.26 (s, 52 H, 26 CH$_2$), 0.88 (t, 6 H, J_{Me,CH_2} 7.1 Hz, 2 *Me*CH$_2$). Anal. Calcd for $C_{90}H_{147}N_3O_{35}$ (1831.15): C, 59.03; H, 8.09; N, 2.29. Found: C, 58.99; H, 8.02; N, 2.14.

*5-Acetamido-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonic acid-(2→3)-6-acetamido-6-deoxy-β-D-galactopyranosyl-(1→4)-[α-L-fucopyranosyl-(1→3)]-2-acetamido-β-D-glucopyranosyl-(1→3)-β-D-galactopyranosyl-(1→4)-β-D-glucopyranosyl-(1→1)-(2*S*,3*R*,4*E*)-2-octadecamido-4-octadecene-1,3-diol* (**39**).—To a solution of 36 (9.5 mg, 3.4 μmol) in MeCN (0.5 mL), cooled to 0 °C, was added M TBAF (80 μL), and the mixture was stirred for 24 h at room temperature, then concentrated. The residue was treated with NaOMe (10 mg) in MeOH (0.5 mL) and THF (0.1 mL) for 24 h at 40 °C, then water (0.1 mL) was added. Workup as described for **38** gave **39** (5.4 mg, 87%) as an amorphous mass: $[\alpha]_D$ −6.1° (*c* 0.1, 1:1 CHCl$_3$–MeOH); ^{1}H NMR (CDCl$_3$): δ 2.09, 1.98, 1.91 (3 s, 9 H, 3 AcN), 1.29 (s, 52 H, 26 CH$_2$), 0.89 (t, 6 H, J_{Me,CH_2} 6.8 Hz, 2 *Me*CH$_2$). Anal. Calcd for $C_{91}H_{148}N_4O_{35}$ (1858.18): C, 58.82; H, 8.03; N, 3.02. Found: C, 58.64; H, 7.82; N, 2.73.

*5-Acetamido-3,5-dideoxy-*D-glycero-α-D-galacto-*2-nonulopyranosylonic acid-(2→3)-6-amino-6-deoxy-β-D-galactopyranosyl-(1→4)-[α-L-fucopyranosyl-(1→3)]-2-acetamido-β-D-glucopyranosyl-(1→3)-β-D-galactopyranosyl-(1→4)-β-D-glucopyranosyl-(1→1)-(2*S*,3*R*,4*E*)-2-octadecamido-4-octadecene-1,3-diol* (**40**).—To a solution of **37** (8.8 mg, 3.1 μmol) in MeCN (0.5 mL), cooled to 0°C, was added M TBAF (80 μL), and the mixture was stirred for 24 h at room temperature, then concentrated. The residue was treated with NaOMe (10 mg) in MeOH (0.5 mL) and THF (0.1 mL) for 24 h at 40°C, then water (0.1 mL) was added. Workup as described for **38** gave **40** (5.2 mg, 93%) as an amorphous mass: $[\alpha]_D$ −9.1° (*c* 0.1, 1:1 CHCl$_3$–MeOH); ^{1}H NMR (CDCl$_3$): δ 1.98, 1.61 (2 s, 6 H, 2 AcN), 1.29 (s, 52 H, 26 CH$_2$), 0.83 (t, 6 H, J_{Me,CH_2} 6.8 Hz, 2 *Me*CH$_2$). Anal. Calcd for $C_{89}H_{146}N_4O_{34}$ (1816.14): C, 58.86; H, 8.16; N, 3.09. Found: C, 58.85; H, 8.06; N, 3.02.

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